Volume 18 Study G-III-D

STATE OF ALASKA

Jay S. Hammond, Governor

Annual Performance Report for

POPULATION STUDIES OF GAME FISH AND EVALUATION OF MANAGED LAKES IN THE UPPER COOK INLET DRAINAGE

by

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Volume 18

Study No. G-III

RESEARCH PROJECT SEGMENT

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Study Title: LAKE AND STREAM INVESTIGATIONS

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Period Covered: July 1, 1976 to June 30, 1977.

ABSTRACT

Limnological studies of various indices of lake productivity including plankton volume, periphyton biomass, chlorophyll production, water chemistry, and morphometric data indicate significant agreement; these parameters may be used as indicators of relative biological lake productivity.

Limnological studies comparing zooplankton trends in a lake rehabilitated with rotenone indicate that treated lakes require between one and two years to reestablish zooplankton production and three years to attain a production level of previous dominance and abundance. It is apparent that none of the abundant species of zooplankton were eliminated from lakes after chemical treatment.

Survival of rainbow trout, *Salmo gairdneri* Richardson, is increased when the competitor species, threespine stickleback, *Gasterosteus aculeatus* Linneaus, is eradicated. Current investigations show that when similar Age I population levels of trout in Johnson Lake were attained for fish in a stickleback environment and in a non-stickleback environment, the cost of raising a catchable fish in a stickleback environment is more than two times as great, and the cost per pound is nine times as great.

Survival of planted Winthrop and Ennis rainbow trout strains in low production lakes is consistently lower than 15% and the cost of producing a catchable sized fish at a 50% harvest level is $0.40 to $2.00 per fish. Stocked wild Alaskan trout have indicated higher survival than Ennis or Winthrop fish in low production lakes and it is evident wild fish may be produced at a significantly lower cost to the creel.

When wild trout of Swanson and Talarik strains are stocked in lakes ranging from high productivity to lakes of low productivity the Swanson fish seem to have greater tolerance to varying lentic environments.

The British Columbia stocking curve, used in equating the number of catchable fry to catchable fingerling one year after stocking, as appli to stocking practices for lakes in the Matanuska-Susitna area has not been consistent in equaling the number of fry to fingerling after stock ing. The curve has not been a successful tool in adjusting stocking schedules for Winthrop fry and Ennis fingerling.

Preliminary hook and line release investigations to help determine the degree of mortality on stocked fish indicate that most mortalities occurred a short time after hooking. When one hook of a treble hook is removed and the remaining barbs filed down, fewer external damages (namely to the eye) occurred, less time was involved in hook extraction (which meant less fish handling time out of the water), and only occasi ally was the lure taken deep.

BACKGROUND

During the early phases of this project plankton abundance was employed as a limnological method for indicating nutritive condition. Primary objectives of plankton sampling in the Matanuska-Susitna Valley lakes (Figure 1) were to: (1) establish the relative plankton abundance in each study lake, (2) identify zooplankton species present during ice free conditions, and (3) eventually develop an index relative to the biological productivity of each lake. This same program continued from June, 1973 through the 1974 field season with no change in sampling design other than the exclusion of two lakes and a change to biweekly instead of monthly sampling. After the plankton indices for study lakes had been determined, seven lakes were excluded from plankton sampling in 1975. The scope of the project was broadened, however, to include analysis of periphyton samples. Primary collection of limnological data continued in 1976 with the additional collection of water samples for chlorophyll a analysis. To date no major modifications have been made in the sampling design; however, for management needs, enough information has been compiled relative to limnological factors and lake productivity to warrant de-emphasis of limnological studies.

Macro-invertebrates were collected in 1974, 1975, and 1976 from three study lakes following chemical treatment of two lakes to eradicate undesirable fish species. The third lake was used as a control lake. Post-chemical treatment studies have continued for three years with analysis of limnological, chemical and invertebrate information. Conclusions from this phase of study have provided information regarding: (1) effects of treatment on invertebrate organisms, (2) time required for a lake to detoxify, (3) time required for pretreatment invertebrate organisms to reestablish, and (4) determination of fish biomass prior to and following chemical treatment under similar stocking densities.

Lake stocking studies were initiated in 1974 to provide information for the development of improved stocking procedures in lakes of varying limnological characteristics. During this phase of the study increased emphasis has been placed on (1) rainbow trout, Talarik and Swanson strain evaluation, (2) production in pounds of fish per surface acre at

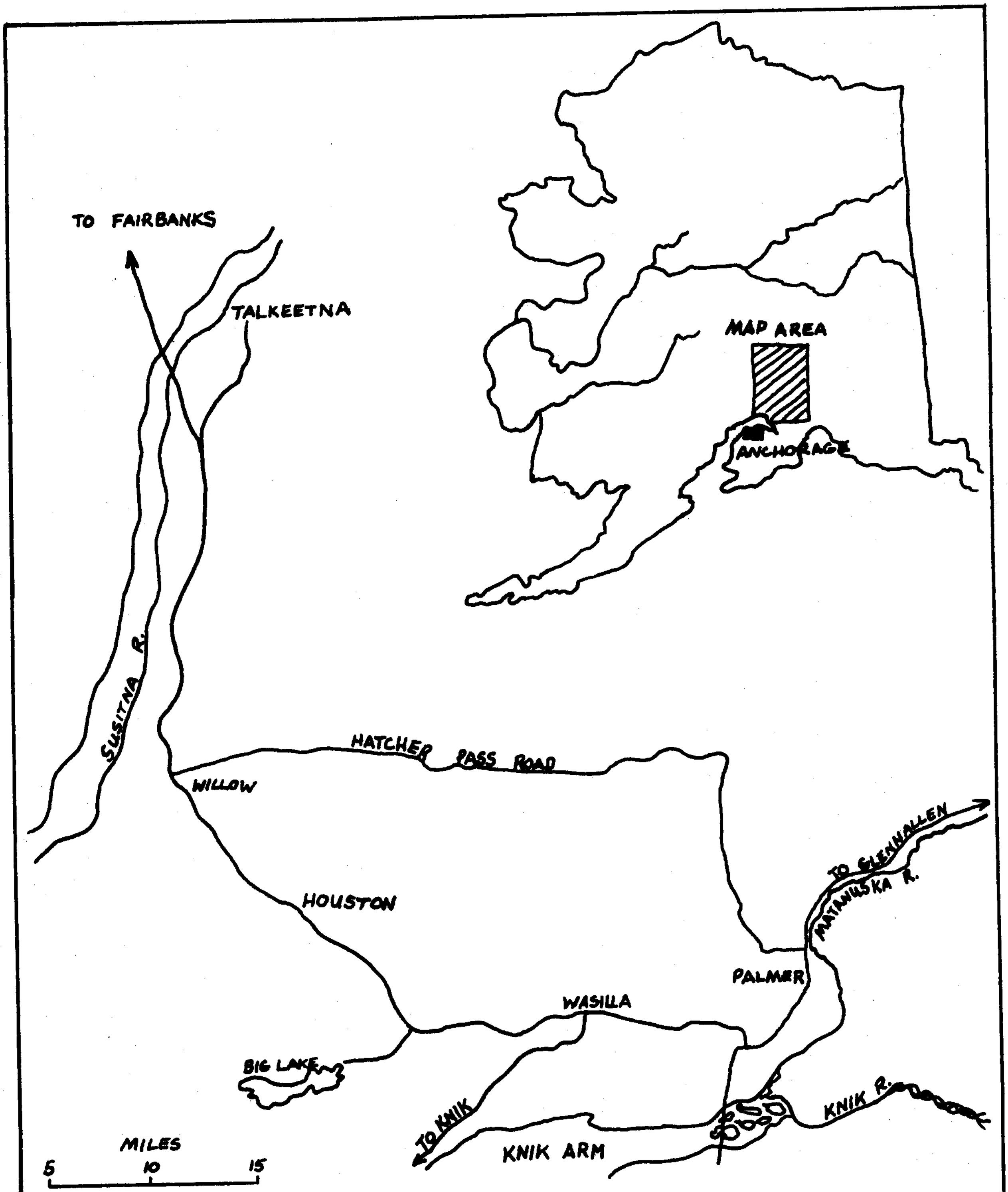


Figure 1. Study Lake Area of Matanuska-Susitna Valleys.

varying stocking densities in lakes of different productivity levels, (3) growth of fish and, (4) survival of fish. Lake stocking studies have provided information to enable: (1) comparisons of fry and fingerling plants; (2) evaluation of Winthrop, Washington, and Ennis, Montana, rainbow trout; and (3) evaluations of the British Columbia stocking curve for converting numbers of larger fish to equivalent numbers of smaller fish. The initial stocking schedules were developed to approximate production capabilities of the Fire Lake Hatchery yet be flexible enough to adjust year-to-year growth variations among different strains of fish.

RECOMMENDATIONS

1. Determine survival, growth, and total yield of Ennis strain trout in Johnson Lake.

2. Determine survival, growth and total yield of Ennis, Swanson, and Talarik strains of rainbow trout in stocked study lakes.

3. Evaluate domestic brood trout with Alaskan brood under varied lentic conditions.

4. Determine cost to the creel for trout in study lakes if survival estimates are available.

5. Continue limnological sampling on selected study lakes to provide representative data of the lake productivity.

OBJECTIVES

1. To determine survival, growth, and total yield of stocked game fishes in landlocked lakes of the area.

2. To determine the effect of rotenone treatment on food organisms utilized by game fishes of the area.

3. To determine limnological conditions which reflect the productivity of study lakes of the area.

4. To provide recommendations for the management of stocked lakes and to direct the course of future studies.

TECHNIQUES USED

Plankton samples were collected biweekly from Memory, Johnson, Matanuska, and Reed lakes. Samples were collected using a 0.5 m ring type plankton net of 130 microns mesh size. A permanent sampling station was established over the maximum depth of each lake. Three vertical hauls were made from each depth of 5 m (16 ft) and 30 m (98 ft), or the bottom, whichever was less. The contents of each haul were washed into bottles containing

40% ethyl alcohol. Samples for identification were preserved in 70% ethyl alcohol. Samples in 40% ethyl alcohol were placed in graduated centrifuge tubes and centrifuged for three minutes at 2,000 rpm in a model CS International Centrifuge. The volume was read to the nearest 0.1 ml and included not only plankton but also organic and inorganic detritus. The volume of detritus, when present, was subtracted from the total volume and recorded.

Zooplankton from Memory, Johnson, Matanuska and Reed lakes were identified by species. Percentages of species abundance for the sample date were determined from a series of three aliquots for each plankton sample.

Macro-zooplankton organisms were collected at permanent stations located on a transect line at 12, 9, 6, 3, 1, 0.5 m depths on Johnson Lake and 6, 3, 1, 0.5 m depths on Memory and Reed lakes. A Petite Ponar Grab, sampling an area of 91.4 cm^2, was used to take biweekly bottom samples from each station. Grab contents were immediately washed through a #20 mesh metal sieve and separated by station depth. Macro-invertebrate organisms were picked from each sample within 24 hours and preserved in 70% ethyl alcohol. Organisms were identified and recorded by station depth.

U.S. Geological Survey techniques (Slack, et al. 1973) were used for collection and analysis of periphyton and the photosynthetic pigment chlorophyll a.

Water samples were collected with a Kemmerer water bottle and dissolved oxygen levels determined by PAO titration. Alkalinity, hardness and pH were determined with the Hach AL-36 WR Field Test Kit. Water temperature and conductivity were measured with a YSI Tele-thermometer and a Hach Model 2510 conductivity meter.

Fish populations were sampled using a 38.1 m X 1.8 m (125 ft X 6 ft) variable mesh monofilament gill net composed of five different mesh panels ranging from 12.7 mm x 50.8 mm (1/2 inch X 2 inch) bar measure. Nets were fished for a minimum of 24 hours. All fish measurements were expressed in fork lengths to the nearest millimeter and in weight to the nearest gram.

All planted fish were anesthetized, hand counted, and marked by hand clipping the right or left ventral fin and/or removing the adipose fin.

Capture of rainbow trout in Johnson Lake for marking purposes was conducted with hook and line. Angling was conducted by two to four anglers. Terminal gear was a hardware lure with a treble hook, later modified to two barbless hooks. The lure was of size 0, 1, 2 and of spinner type. No artificial flies, worms, fish eggs or any other live bait was employed. Fish taken with hook and line were landed with a small dip net and hooks were removed with needle nose pliers. All trout were adipose clipped, as soon as possible after hooking, and transferred to a holding pen stationed in Johnson Lake. The holding pen was checked several times daily for a 24-hour period and mortalities enumerated. Fish were released after the 24-hour period. After a two week period, fish were captured using 38.1 m x 1.8 m (125 ft x 6 ft) variable mesh monofilament gill nets composed of five different mesh panels ranging from 12.7 mm to 50.8 mm (1/2 to 2-inch) bar measure. Capturing of marked fish continued over a 3-week period for 12 days.

Rainbow trout population size in Johnson Lake was determined by using Chapman's modification of the Petersen estimator (Ricker, 1975).

FINDINGS

Results

Limnological Studies:

Limnological studies under this research project have attempted to identify those parameters that encompass variables influencing survival and growth of fish. If the combination of these variables represents the productivity of a lake, then data expressing degree of productivity should provide a basis for relating stocking intensity to a specific body of water. Potential indicators of biological productivity investigated in this phase of study have been (1) plankton abundance, (2) identification of micro and macro invertebrates, (3) periphyton analysis, (4) chlorphyll *a* analysis, and (5) water chemistry analysis. Parameter indices were derived after the physical aspects of a body of water were taken into consideration.

Commonly a lake is comprised of two separate regions (1) the upper waters of photosynthetic production (trophogenic zone) and, (2) the lower strata of decomposition (tropholytic zone). During summer stagnation the trophogenic zone is essentially the epilimnion, the area of high dissolved oxygen concentration, since it includes the region of water mixing and photosynthetic activity. In shallow lakes the trophogenic zone encompasses the entire water column. In deeper lakes, the extent of the trophogenic zone is generally less than the total lake volume but possibly greater than in shallow lakes. Development of indices relative to lake productivity must take into account the volume of water suitable to plankton production. Consequently, quantitative comparisons of shallow to deep lakes are complicated because of the variance in the trophogenic zone depth.

The plankton index (PI) was developed by first defining the trophogenic zone in deep lakes as the maximum depth of high dissolved oxygen penetration estimated from dissolved oxygen profiles and then incorporating this value into the PI computations; i.e., the depth of high dissolved oxygen for each sampling date was divided into the mean centrifuge volume for that data and multiplied by a factor of 10, resulting in the PI for that lake. The PI of shallow lakes was calculated by dividing the seasonal average centrifuge volume by the depth of the plankton tow, then multiplying by a factor of 10. A ranking according to the numerical value of the relative plankton productivity for 1973 through 1976 is presented in Table 1.

Table 1. Summary of Plankton Indexes for Study Lakes, 1973-1976.

Lake	Plankton Index			
	1973	1974	1975	1976
Lucille*	7.00	7.65		
Seymour*	1.67	8.33		
Long*	2.87	3.58		
Matanuska	16.19	5.46	5.20	4.4
Johnson**	4.89	3.09	1.60	3.9
Reed				5.1
Short Pine*	0.63	1.95		
Loon*	2.29	1.80		
Memory**	0.86	0.69	1.19	2.6
Christiansen*	0.25	0.45		
Marion	0.10	0.46		

* Chemically treated with rotenone in fall, 1972.
** Chemically treated with rotenone in fall, 1973.

Throughout this phase of study, considerable attention was given to cl ing of the plankton net after sampling periods. Sampling error occasi developed when the plankton net became clogged with plankters affecting filtering efficiency. Also, in some lakes centrifuge plankton volumes were underestimated due to large volumes of gelatinous substances preventing efficient centrifuging of samples in the later months of summer. Sources of this error were attributed to the cladoceran, <u>Holopedium gibberum</u>, in Loon Lake and to a form of algae in Seymour Lake (Kalb, 1975). Correction for volumes in the cases of Loon and Seymour lakes was not accomplished because centrifuge error was not known until after spinning of samples. To alleviate this problem such samples were centrifuged twice with acceptable results. Other sources of possible error are (1) unknown quantities of detritus present in plankton samples possibly increasing volume, (2) cyclic changes in the plankton community that would escape being recorded if sampling were not frequent enough, (3) error introduced through centrifuging, i.e., different settling rates, and densities of different organisms, (4) error introduced by an inconsistency of sampling techniques, i.e., different personnel doing sampling, (5) PI is not stable from one year to the next, possibly due to environmental factors; however, relative comparisons would be meaningful, and (6) alteration of plankton production caused by chemical treatment to eradicate undesirable fish.

Examination of plankton volumes for each sampling date in 1973 (Figures 2 and 3) suggests variation of plankton abundance in untreated and in rehabilitated lakes. Studies were initiated to determine the detrimental effect of rotenone treatment on food organisms utilized by game fish species and the ability of those organisms to reestablish following detoxification (Kalb, 1974). Studies on the effect of emulsified rotenone on food organisms have been conducted by others (Kiser, et al., 1963; Brown and Ball, 1943; and Smith, 1939) who have observed a deleterious effect on planktonic and bottom organisms. These studies were conducted in areas where favorable climatic conditions promoted a rapid detoxification of the lakes.

Plankton volumes for untreated lakes in the Matanuska-Susitna Valleys have higher measured centrifuge volumes in June and early July, undoubtedly correlated to higher nutrient levels (following spring turnover) and extended solar radiation. In every case, a decline of volume in late summer is attributed to utilization of nutrients, thermal stratification restricting circulation or regeneration of nutrients into the upper water layers, and to a degree influence of fish populations grazing on plankters; however, selection of zooplankton as a food item by rainbow trout may be influenced by the size of plankton organisms. Brynildson and Kepinger (1973) studying growth, production and food of rainbow trout and brown trout, <u>Salmo trutta</u> Linnaeus, found planktonic crustaceans 1 mm and larger to be the staple food of fish less than 400 mm in length, and no stomachs contained plankton less than 1 mm in size. Galbraith (1967) also reported that rainbow trout selectively consumed <u>Daphnia sp</u>. 1.3 mm in size and greater. In conjunction with this information, only plankters greater than 1 mm in size are identified and recorded by percent composition for each sampling date from Matanuska-Susitna study lakes (Figures 4, 5, and 6).

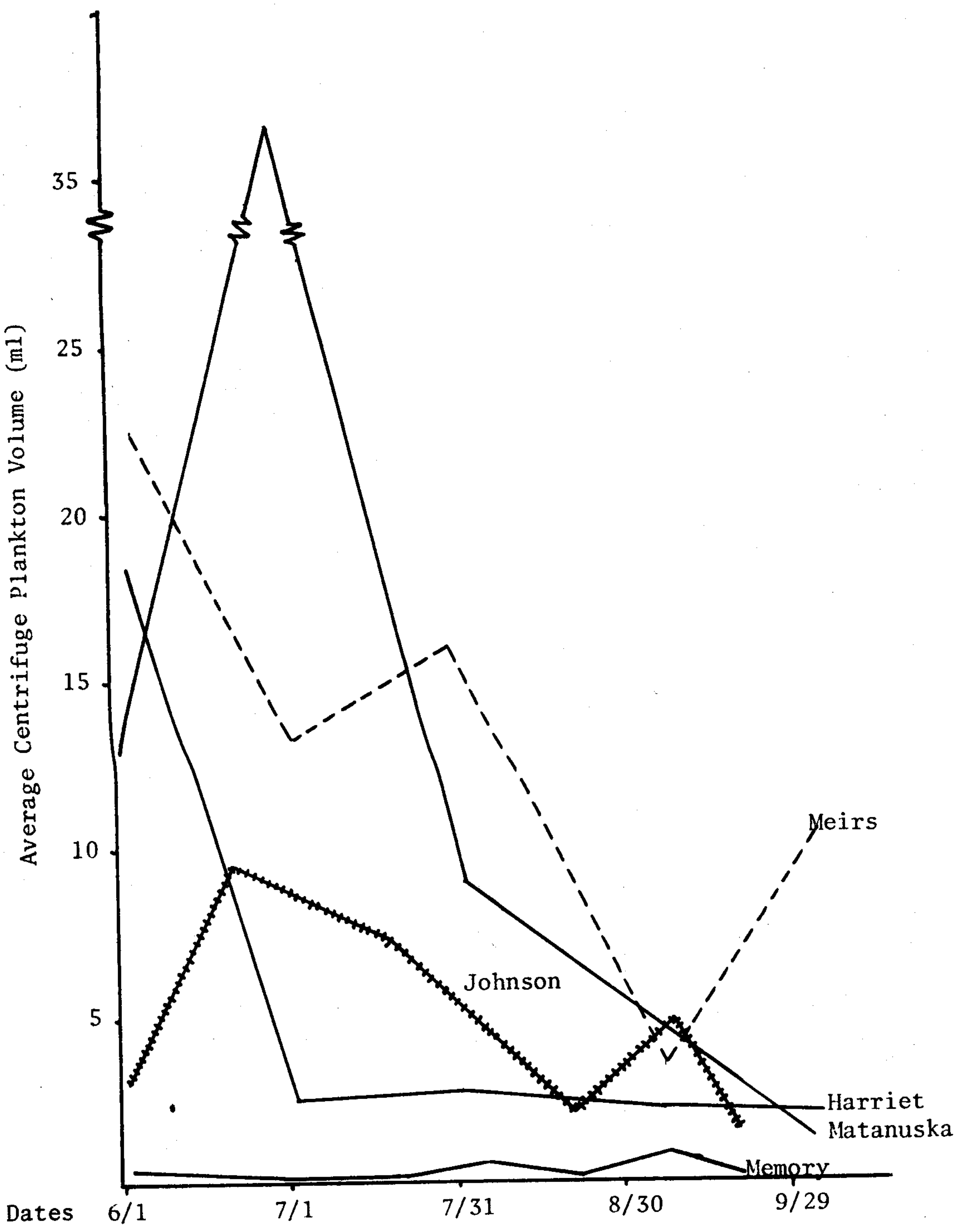


Figure 2. Plankton Volumes by Date for Untreated Lakes, 1973.

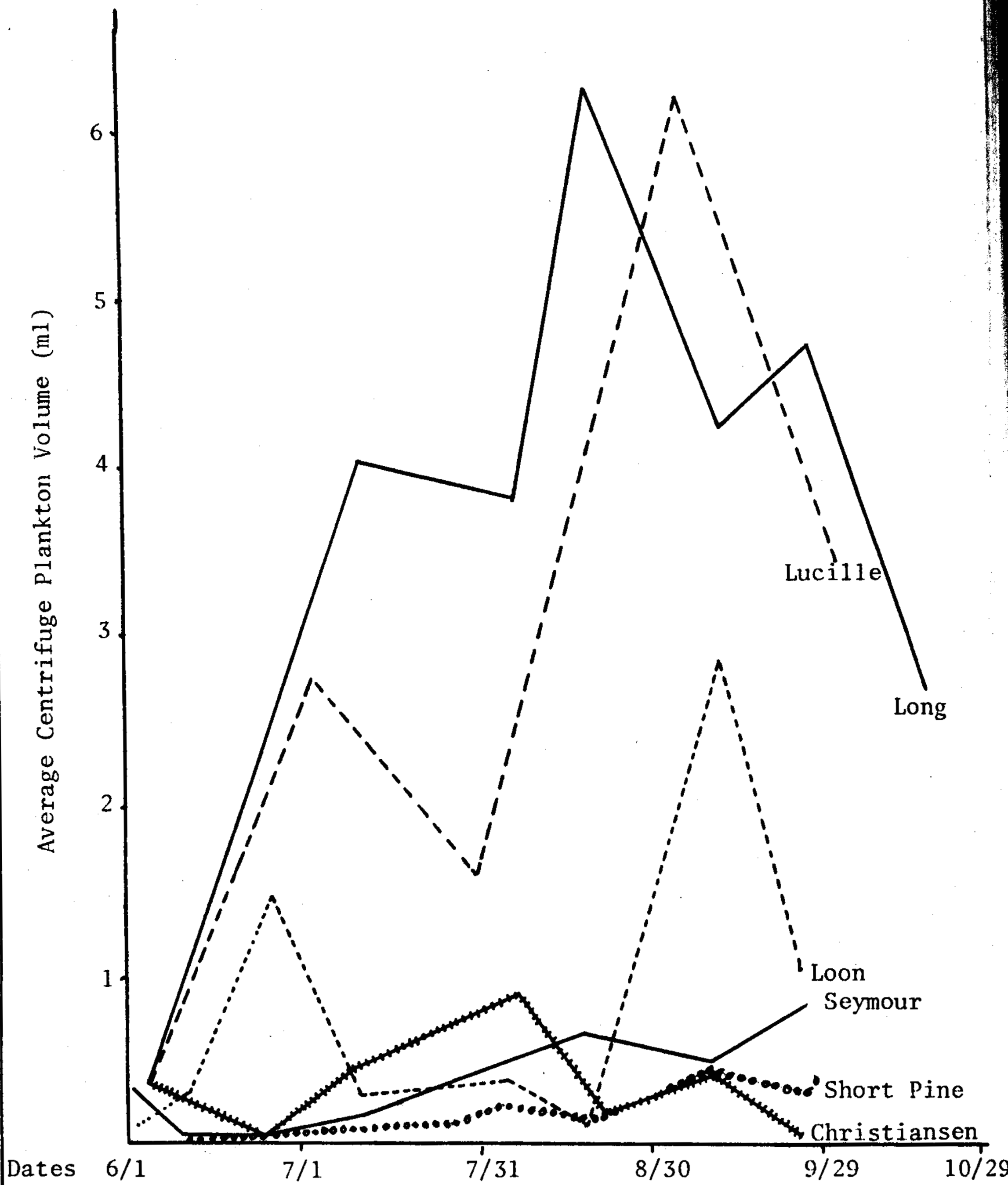


Figure 3. Plankton Volumes by Date for Treated Lakes, 1973.

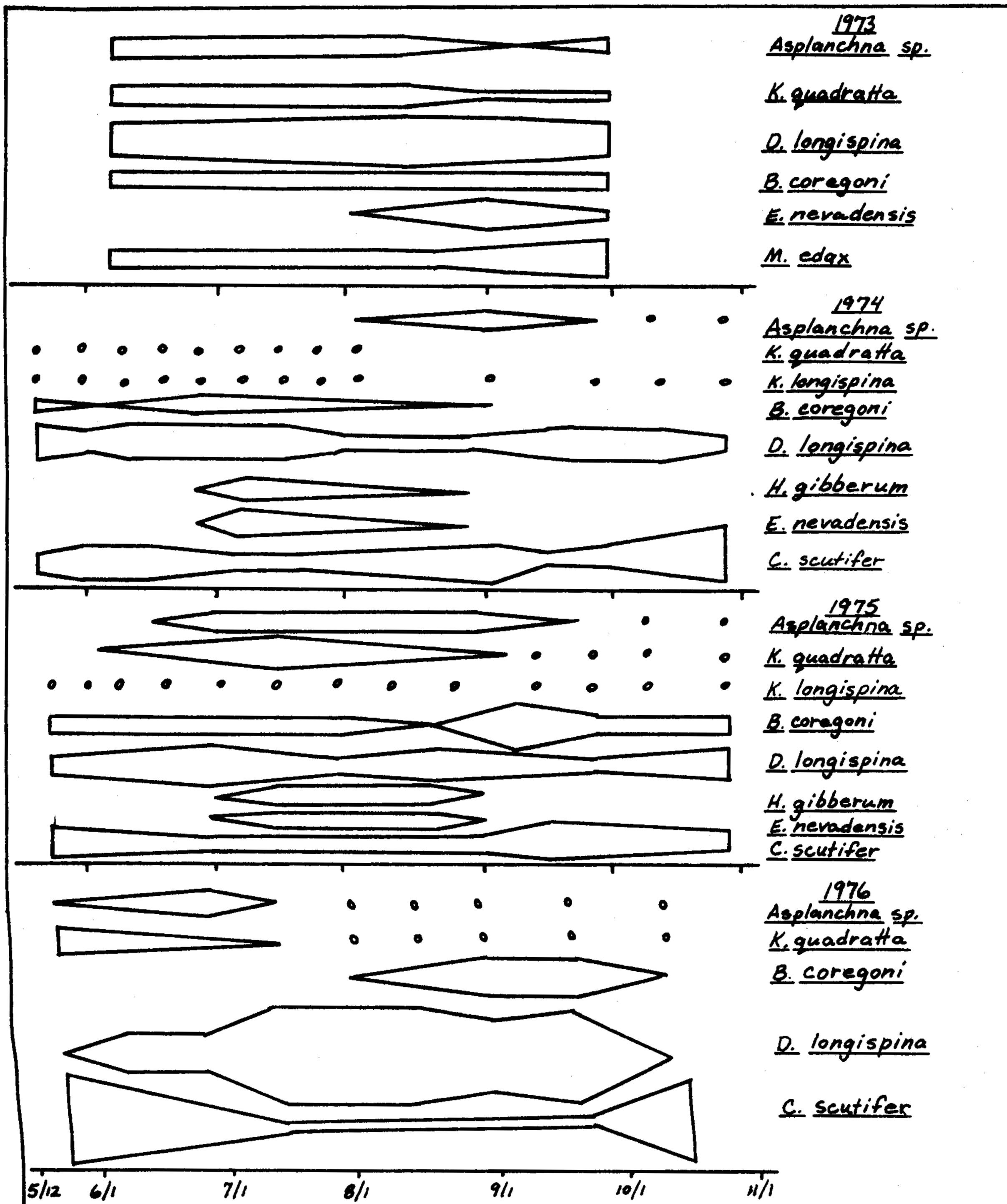


Figure 4. Relative Width of Geometric Figures is the Percent Species Composition of the Plankton Community on that Sampling Date for Matanuska Lake.

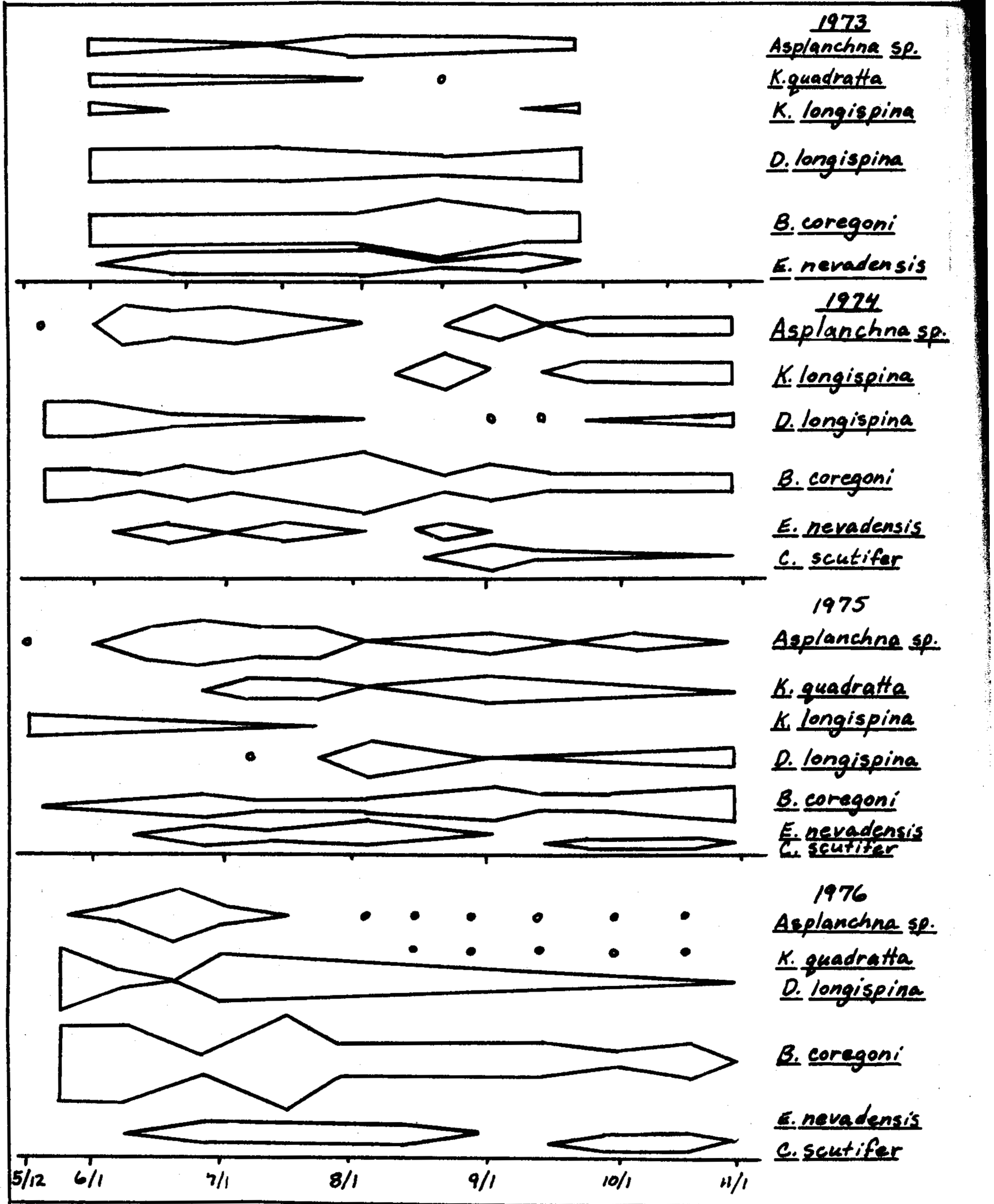


Figure 5. Relative Width of Geometric Figures is the Percent Species Composition of the Plankton Community on that Sampling Date for Johnson Lake.

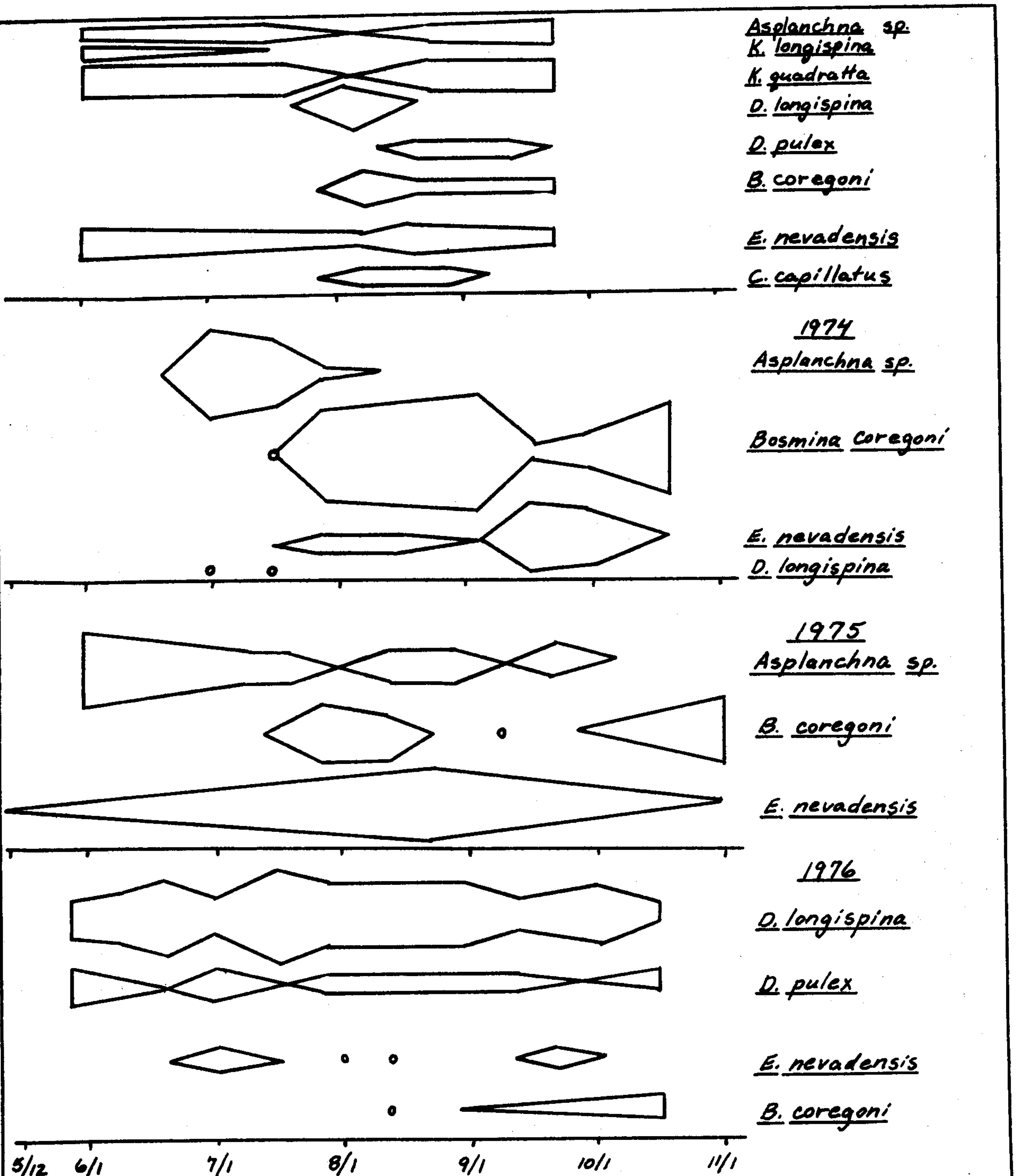


Figure 6. Relative Width of Geometric Figure is the Percent Species Composition of the Plankton Community on that Sampling Date for Memory Lake.

In Alaska the present practice is to chemically treat lakes prior to formation of a winter ice cover reducing the deterioration rate of rotenone. Since this prolonged toxicity is believed to hinder reestablishment of invertebrate organisms during the following ice free months, a study was initiated to determine the effects of rotenone on those organisms.

Johnson and Memory lakes were chemically treated in September, 1973 with concentrations of 0.6 ppm and 0.8 ppm Pro-Noxfish, respectively, to remove threespine stickleback, Gasterosteus aculeatus Linneaus. Duration of toxicity in the two lakes was determined using live fish suspended in cages, and by the chemical test for rotenone described by Post (1955). By February 26, 1974, the concentration in Johnson Lake had dropped to approximately 0.2 ppm (Kalb, 1975). Kalb (1974) suspended chinook salmon fingerlings, Oncorhynchus tshawytscha (Walbaum), in cages at 10 foot intervals from the surface to the bottom on April 1, 1974. After four days all fish were still alive, indicating detoxification had occurred. Memory Lake still retained slightly greater than 0.2 ppm rotenone when tested on February 26, 1974. Chinook salmon were similarly suspended in Memory Lake on April 1 at the 5 and 12 foot levels; however 50% mortality was incurred by the third day in the bottom cages. On the fourth day 80% of the fish had died at both depths, suggesting toxic levels of rotenone were still present. Subsequent chemical analyses indicated lake detoxification by the end of March.

In chemically treated lakes seasonal variation of plankton abundance differed from that occurring in untreated lakes. There is an increase in plankton volumes with the progression of summer in treated lakes (Figure 3) while untreated lakes exhibit the opposite (Figure 2). This result suggests plankton productivity was retarded by the application of rotenone. Kalb (1974), in reference to the 1973 field season, states: "It is unknown if the prolonged toxicity severely affects reestablishment of food organisms in the short productive season of northern lakes." Chlupach (1976) states: "When comparing zooplankton trends in treated lakes (Memory and Johnson) with a non-treated lake having a stable zooplankton community (Matanuska Lake) zooplankton reestablish between one to two years; however, none of the abundant species of zooplankton were eliminated from lakes after chemical treatment."

Previous investigations by Kiser, et. al., (1963) have verified the detrimental effect of rotenone on plankton species. He found that the abundance of open-water zooplankton species, especially cladocerans and copepods, was greatly reduced in two lakes treated with 0.5 ppm and 1 ppm concentrations of 5% rotenone. Zooplankton species were not completely eliminated but did not begin to return to pretreatment levels until five weeks after the water had become non-toxic to fish.

A list of species and relative species composition per plankton tow are recorded in Table 2 and Figures 4, 5 and 6, for Matanuska, Johnson, Memory and Reed lakes. Johnson and Memory lakes were selected for analysis because of prior chemical treatment with rotenone, while Matanuska Lake represented a stable non-treated lentic environment. Reed Lake plankton hauls were directed towards determination of a plankton index.

Table 2. Organisms Occurring in Study Lakes Compiled from Plankton Samples, 1973-1976.

	Matanuska				Johnson				Memory				Reed
	73	74	75	76	73	74	75	76	73	74	75	76	76
Rotifera													
Asplanchna sp.	X	X	X	X	X	X	X	X	X	X	X		X
Keratella quadratta	X	0	X	0	X		X	X	X		0		
Kellicottia longispina		0	0	0	X	X	X	X	X	0			0
Cladocera													
Daphnia longispina	X	X	X	X	X	X	X	X	X	0		X	X
Daphnia pulex									X				
Bosmina coregoni	X	X	X	X	X	X	X	X	X	X	X	X	X
Holopedium gibberum		X	X	X									
Copepoda													
Epischnra nevadensis	X	X	X	X	X	X	X	X	X	X	X	0	
Cyclops scutifer		X		X		X	X	X					X
Cyclops capillatus									X				
Cyclops vernalis						X							
Mesocyclops edax	X					X	0						
Amphipoda													
Gammarus lacustris						X	0	0					
Ostracoda										0			
Insecta													
Corixidae						0	0	0			0	0	0
Chironomidae						0	0	0			0	0	

X Denotes presence greater than 1%
0 Denotes presence less than 1%
Blank spaces denote zero occurrence

Species composition is of no present consequence but is recorded in the event that future food habit studies of rainbow trout are conducted using fish from this lake.

As previously stated, Kiser, et al. (1963) found the abundance of zooplankton, especially cladocerans and copepods, were greatly reduced in lakes treated with rotenone. In post-treatment plankton samples, from Matanuska-Susitna study lakes, seasonal succession of organisms suggests that early seasonal plankton production in 1973 was of less complex organisms, such as rotifers and protozoans. Species succession progressed to cladocerans and copepods with the advance of summer. However, in 1974 cladocerans and copepods were the dominant species present in samples from the same lakes; and rotifers, if present at all, occurred only in small numbers (Kalb, 1975).

Kalb (1975) noted that chemical treatment appeared to retard plankton abundance in Memory Lake, as early 1974 samples were void of organisms. Plankton did not begin to reappear until the end of June, beginning with Asplanchna sp. (rotifers) and succeeding to crustaceans. Sampling in 1975 supports Kalb's observations, as plankton appeared in late May and early June, beginning with rotifers and succeeding to crustaceans. The overall trend of plankton species dominance and catch composition by percent species abundance throughout 1975 sampling follows the same trend exhibited during 1974 sampling, which indicates return to possible previous plankton species composition. With 1976 sampling, little change in species composition occurred; however, Daphnia sp. reappeared in greater concentrations compared to the less than 1% composition occurrence in 1975. Based on successive species composition trends 1974-1976 and progressively higher plankton volumes, Memory Lake is assumed to have returned to pretreatment species composition and abundance levels.

Plankton abundance in Johnson Lake (1975) did not increase in early June as it had in 1974, yet plankton centrifuge volumes in 1976 exhibit a similar trend to 1974 (Figure 7). Evidence of this is also indicated by comparing relative plankton species composition for 1974 through 1976 (Figure 5). As chemical treatment occurred in 1973 no obvious cause can be determined for this response and is attributed to some environmental factor not measured in the scope of this study.

In June, 1974 and 1976, there were strong pulses of Daphnia longispina and Bosmina coregoni in Johnson Lake; however, in June 1975 strengths of equivalent magnitudes did not develop for either species. Plankton volumes were increased from 1974 to 1975 probably because of the noted increase in numbers of Epischura nevadensis and Cyclops scutifer; however, plankton volumes also increased from 1975 to 1976 and were not attributed to greater numbers of E. nevadensis and C. scutifer but to D. longispina and B. coregoni. Data were not available to indicate reasons for these effects; however, cladoceran levels were thought to have possibly been altered by introduced rainbow trout after lake detoxification. With the early seasonal (1976) appearances of D. longispina and B. coregoni plus another introduction of rainbow trout, previous zooplankton trends are thought to be the result of an unmeasured environmental

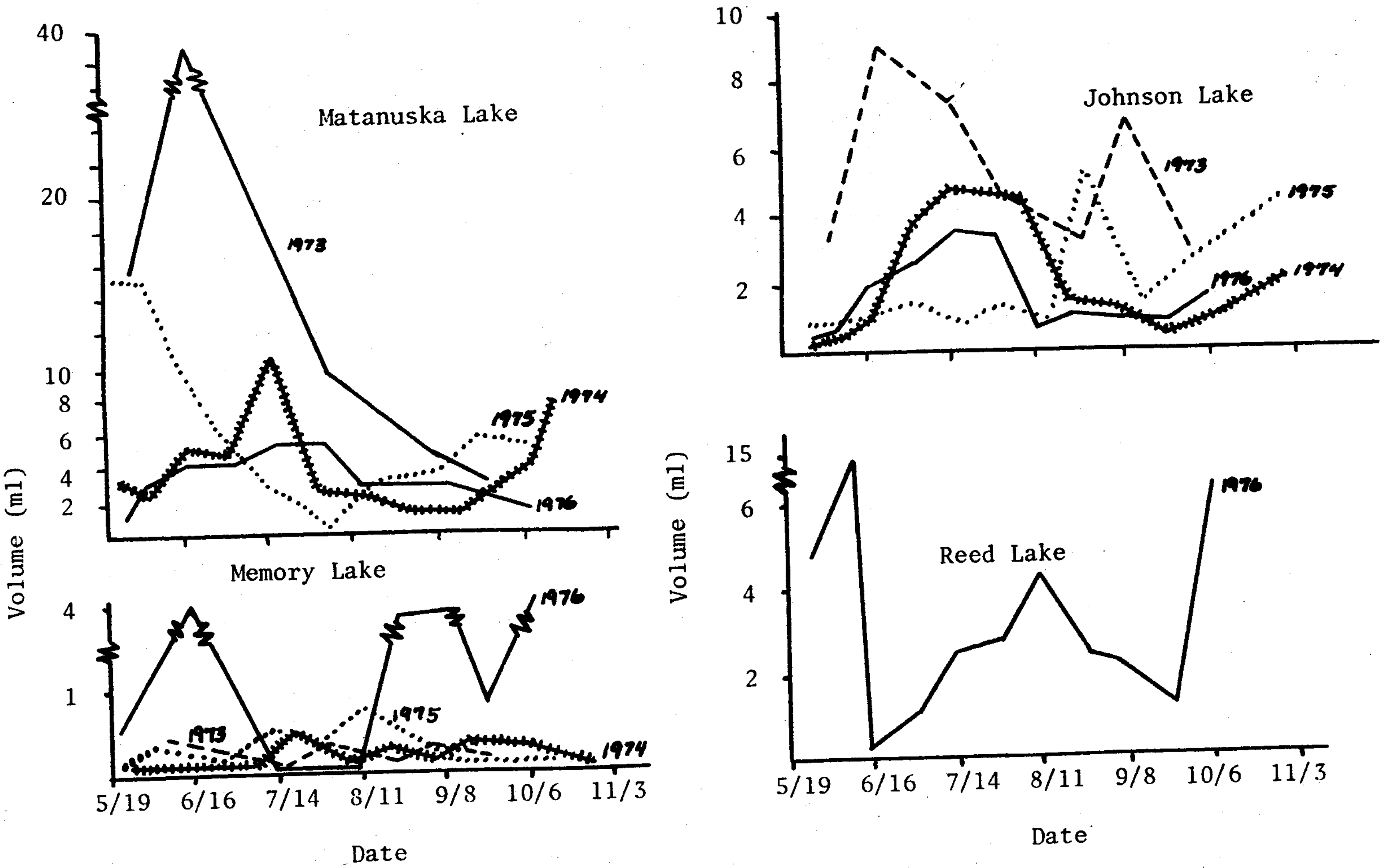


Figure 7. Mean Plankton Volumes in Study Lakes, 1973-1976.

factor or factors; however, the overall trends of species dominance from 1974 through 1976 were similar.

No mid-water cladoceran or copepod species disappeared in lakes after treatment with rotenone. Prior studies on the effect of rotenone on zo plankton (Kiser, et al., 1963) indicate adult cladocera and copepods coming in contact with rotenone are killed, but the species survive by means of parthenogenetic summer eggs and by the tough ephippial eggs which are unaffected by rotenone. Parthenogenetic reproduction throu development of an unfertilized egg is not uncommon among invertebrate Successful reproduction is dependent on a protective capsule (ephippi which is resistant to drying, freezing, and rotenone, thus explaining the perpetuation of cladocerans and copepods. Also, complete rotenon application is very unlikely, particularly around highly vegetated sh and beach areas where invertebrates may have escaped the rotenone. Kiser, et al., (1963) also suggest a high detoxification rate of rote- none by dense organic material in the weedy habitats, and that concei ably, species may also enter the lake from outside. This suggests th elimination of cladocerans or copepods by rotenone is quite unlikely.

Matanuska Lake, an untreated lake, had similar seasonal trends of speci dominance, succession and catch composition (Figure 4) throughout the plankton sampling period 1973-1976 indicating a stable zooplankton community.

Micro-invertebrates were collected to determine the effect of rotenone on plankton volumes and species composition. The project was also designed to collect macro-benthic invertebrates under pre- and post- chemical treatment conditions. Benthic organisms were collected at three meter intervals in Johnson and Memory lakes (Table 3). The groups of organisms identified from Memory Lake were amphipods, Gammarus lacustris; chironomids, Cryptochironmus and Procladius sp.; caddis flies, Oecetissp; clams, Pisidium sp.; snails, Gyrallus sp; worms, Lumbriculus sp.; leeches, Glossophonia heteroclita; and unidentified mites. Benthic organisms collected from Johnson Lake were of the same groups as Memory; however, more species diversity was noted with the addition of: beetles, Galerucella sp.; caddis flies, Limnephilidae; dragon flies, Somatochlora sp.; chironomids, Einfeldia sp., Phaeonospectra sp., Polypedium sp., Tanytarsus sp., Dierotendipes sp.; leeches, Helobdell stagnalis; worms, Ilyodrilus sp.; and unidentified mayflies of Baetidae. Both Memory and Johnson lakes' pre- and post-treatment data indicate none of the Benthic species were eliminated by chemical treatment. Benthic organisms found to be most abundant prior to and after chemical treatment were species of chironomids, amphipods, and freshwater clams with only minor numbers of the other organisms present. The following spring after chemical treatment, there was a decrease in numbers of benthos particularly among amphipods, chironomids, and clams (Chlupach, 1976); however, these same organisms have increased in numbers again as was indicated by spring sampling in 1975 and 1976.

The predominant points of interest deal with the production links and their interrelation, i.e., phytoplankton, zooplankton (pelagic and benthic, macro and micro), and fish through which organic matter passes.

Table 3. Benthic Macroinvertebrates Occurring in Study

Identification	Group	Johnson Lake 73	Johnson Lake 74**	Johnson Lake 75	Johnson Lake 76	Memory Lake 73	Memory Lake 74	Memory Lake 75	Memory Lake 76
		X		X	X	X	X	X	X
Gammarus lacustris	amphipods	X		X	X	X	X	X	X
Procladius sp.	chironomids					X			
Cryptochironomus sp.	chironomids					X			
Dicrotendipes sp.	chironomids	X							
Chironomus sp.	chironomids	X							
Einfeldia sp.	chironomids	X							
Polypedium sp.	chironomids	X							
Tanytarsus sp.	chironomids	X		X	X	X	X	X	X
Gyrallus sp.	snails	X		X	X	X	X	X	X
Pisidium sp.	clams	X			X	X	X	X	X
Glossophonia heteroclita	leeches	X							
Helobdella sp.	leeches					X	X	X	X
Graptocorixa sp.	bugs					X	X	X	X
Lumbriculus sp.	worms	X		X	X				
Ilyodrilus sp.	worms	X		X	X				
Peloscolex sp.	worms	X		X	X				
Galeruculla sp.	beetles	X		X	X				
Limnephilidae	caddis flies					X			X
Oecetis sp.	caddis flies	X			X				
Somatochlora sp.	dragonflies								

* La Perriere identified all benthic organisms in 1973.
** 1974 samples for Johnson Lake were not available
Due to finite microscopic work in identifying chironomids to species, samples in 1974-1976 were identified to just the chironomid group.

The main factors influencing the dynamics of the development of macroscopic bottom fauna (apart from the extreme chemical and physical conditions in the water bodies) are the sources and supply of food on the one hand, and on the other the direct or indirect influence of the fish (Llellak, 1965). Llellak also states that one may assume that the main source of food for the macrobenthos is the substrate in which the animals live, since in the sediments and the underwater soils there are many substances which are of energy giving value and dead plankton descends from the water column above. Thienemann (1954) in an analysis of the food of the bottom fauna proved that the majority of benthonic animals, and not only worms, but larvae of insects as well, consume the mud and detritus. A number of animals obtain food by filtering the water or picking the food from bottom surfaces and also live on the remains of the dead plankton falling to the bottom. To some degree, bottom fauna is influenced by fish populations either directly by feeding or indirectly by feeding on zooplankton which influences the quantity and composition of food falling to the bottom. However, this is no doubt influenced by the fish dependency on a quantity of more readily obtainable food.

Based on available data from Matanuska-Susitna study lakes, changes in the dynamics of invertebrate populations after chemical treatment with rotenone suggest that benthic organisms are dependent on nutrients from the waters above. Since chironomids, amphipods, clams and other benthos obtain their food from the bottom surface, or by filtration of water, they are dependent on an uninterrupted supply of food. Chemical treatment then takes on a twofold effect as far as benthic invertebrates are concerned, i.e., (1) the once continuous food supply for benthic invertebrates dies off and settles to the bottom and (2) benthic invertebrates themselves die off as a direct result of chemical treatment. Benthic sampling the following spring yielded very few organisms (probably ones that escaped by incomplete rotenone application) so major propagation through reproduction was eliminated due to lack of adult benthos. However, through parthenogenetic reproduction, with the aid of a drying-freezing resistant egg capsule (also rotenone tolerant), cladocerans, copepods, and rotifers survived and were captured in spring plankton hauls. These organisms, through their feeding and continued propagation, affect the amount of food settling to the bottom, thus altering the rate of benthic invertebrate recovery. Consequently, the different trophic levels and life histories of invertebrates in part govern their relative recovery after chemical treatment.

Other potential indicators of biological productivity investigated in this study are periphyton and chlorophyll a. Periphyton comprises all organisms (except macrophytes) which are attached to a substrate but do not penetrate into it. U.S. Geological Survey techniques (Slack, et al. 1973) for collection and analysis of periphyton dry and ash weights were utilized. Inorganic substrate stations were placed in Matanuska, Johnson, Memory, Canoe, and Reed lakes. Recommended substrate exposure is 14 days; but to insure sufficient periphyton colonization, samples were periodically checked and removed after 30 days. Biomass data could not be determined for two lakes because of vandalism to glass substrates. Subsequent sites were located and substrate markers placed below the water's surface; however, this did not prevent destruction of the sampling apparatus in either lake. Another problem encountered, that we were unable to detect and compensate for, was the possible excessive dry ash weight due to inorganic matter in biomass samples. Data are analyzed from Johnson, Memory and Canoe lakes. Periphyton biomass (g/m^2) for field seasons 1975 and 1976 are presented in Table 4.

Photosynthetic pigment concentrations, particularly chlorophylls, serve as quantitative and qualitative indicators of phytoplanktonic and periphytic biomasses for relative assessment of local study lakes. Ratios between the different forms of chlorophyll are believed to indicate the tasonomic composition or the physiological condition of an algal community (Creitz and Richards, 1955). Due to lack of equipment, time and contractual monies, concentrations of photosynthetic pigments were analyzed only on a limited basis. Chlorophyll a pigment was analyzed because of its ease in separation from other pigments. The process involves filtration of a designated water sample; the phytoplankton cells retained on the filter are disrupted to facilitate extraction of pigments with 90% acetone. Concentration of chlorophyll a is based on absorbance measurements at four different wave lengths correcting with a 90% acetone blank. Filtration of water samples from Memory, Johnson, and Canoe lakes was difficult because of suspended materials (possibly from leaves and other plant materials). In some instances the stress on filtration equipment exceeded safety levels; consequently, other samples were obtained or sampled at a later date. In any case, the presence of this matter would result in erroneous chlorophyll a values. Another source of error was the presence of phaeopigments or the decomposition products of chlorophyll. However, the spectrophotometric method provides a means for determining phaeopigment concentration and results were corrected for this. Chlorophyll values are compared on a relative basis for study lakes at the end of the field season because sampling dates varied, aquatic conditions change rapidly, and light intensity varied depending on conditions. Chlorophyll a values determined from study lakes are presented in Figures 8 and 9.

Plankton abundance, micro- and macro-invertebrates, periphyton, phytoplankton, and chlorophyll pigment production, are all in part dependent on the physical and chemical characteristics of a particular lentic environment. Detailed physical and chemical characteristics have been summarized for Matanuska-Susitna Valley lakes by Engel (1974) and Watsjold (1975). Thirty-one Matanuska-Susitna Valley lakes range in surface area from 5 to 362 acres and from 17 to 177 feet in depth. Some lakes have permanent outlets, whereas others are landlocked or have intermittent outlet discharge. Although most deep lakes are dimictic, some do not mix completely during each circulation period. Incomplete vernal mixing occurs more often than incomplete fall mixing because breakup occurs shortly before the summer solstice when heat transfer to the water is rapid, causing stratification which limits circulation. Monitoring of selected study lakes indicates summer thermal patterns were almost identical the past four years. Lakes deeper than six or seven meters (20 to 23 feet) were thermally stratified for a portion of the summer, those with depths of 7 to 13 meters (23 to 43 feet) had hypolimnia that are generally above 40°F in summer, whereas deeper lakes

Table 4. Periphyton Biomass for Study Lakes, 1975-1976.

	1975				1976				
	Biomass (g/m^2) by Date				Biomass (g/m^2) by Date				
Lake	9/1	10/1	10/23	Total	7/1	8/1	9/1	10/1	To[illegible]
Matanuska	7.12	5.36	5.52	18.00		6.19		7.81	[illegible]
Johnson	5.65	3.41	2.49	11.55	4.65	3.71	2.98	2.11	13[illegible]
Canoe					7.51	5.17	5.65	5.43	23[illegible]
Memory	2.32	1.81	1.43	5.56	1.83	2.47	0.91	0.81	6.[illegible]
Reed					1.56	2.01			

* Total biomass not available due to vandalism of artificial substrates.

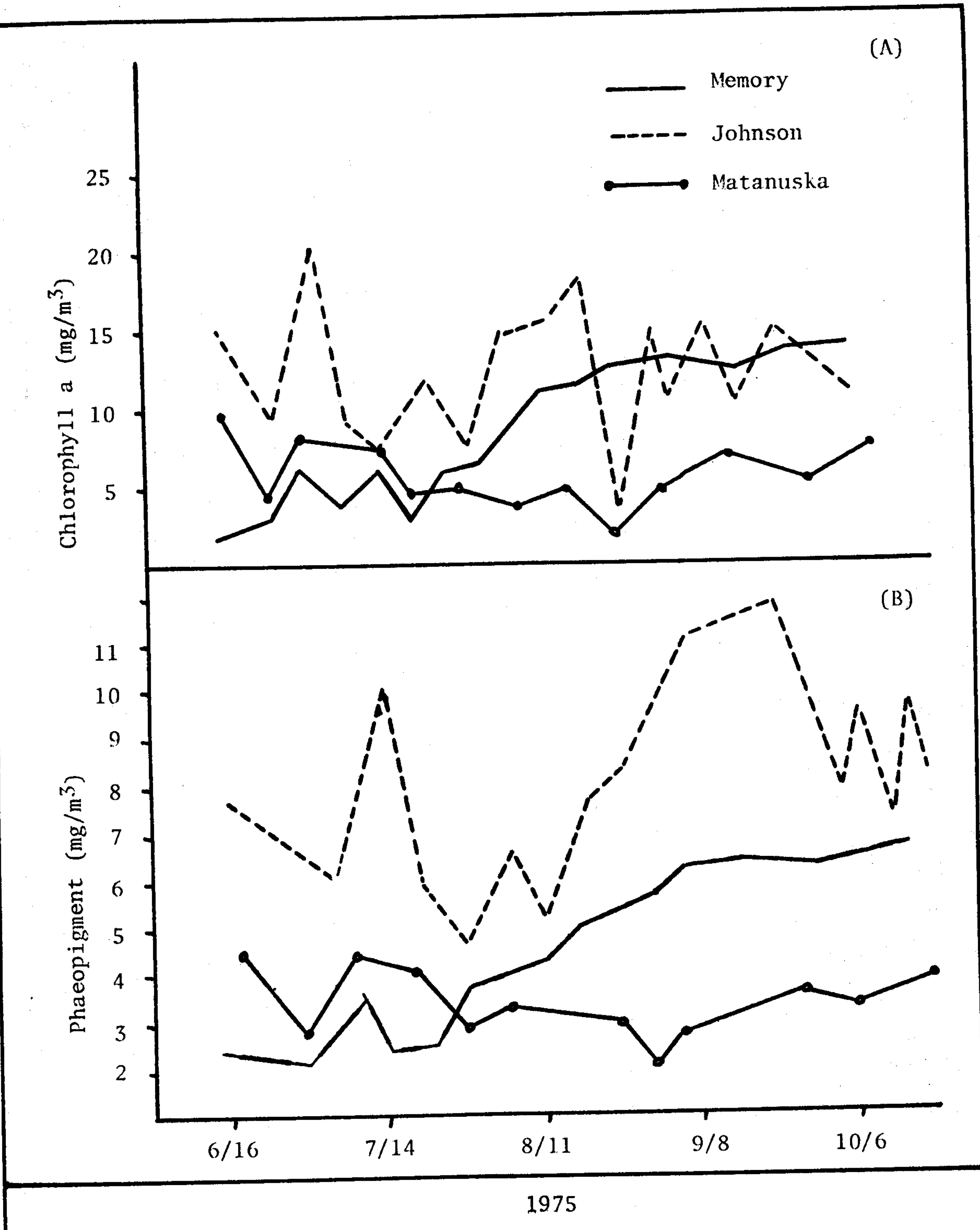
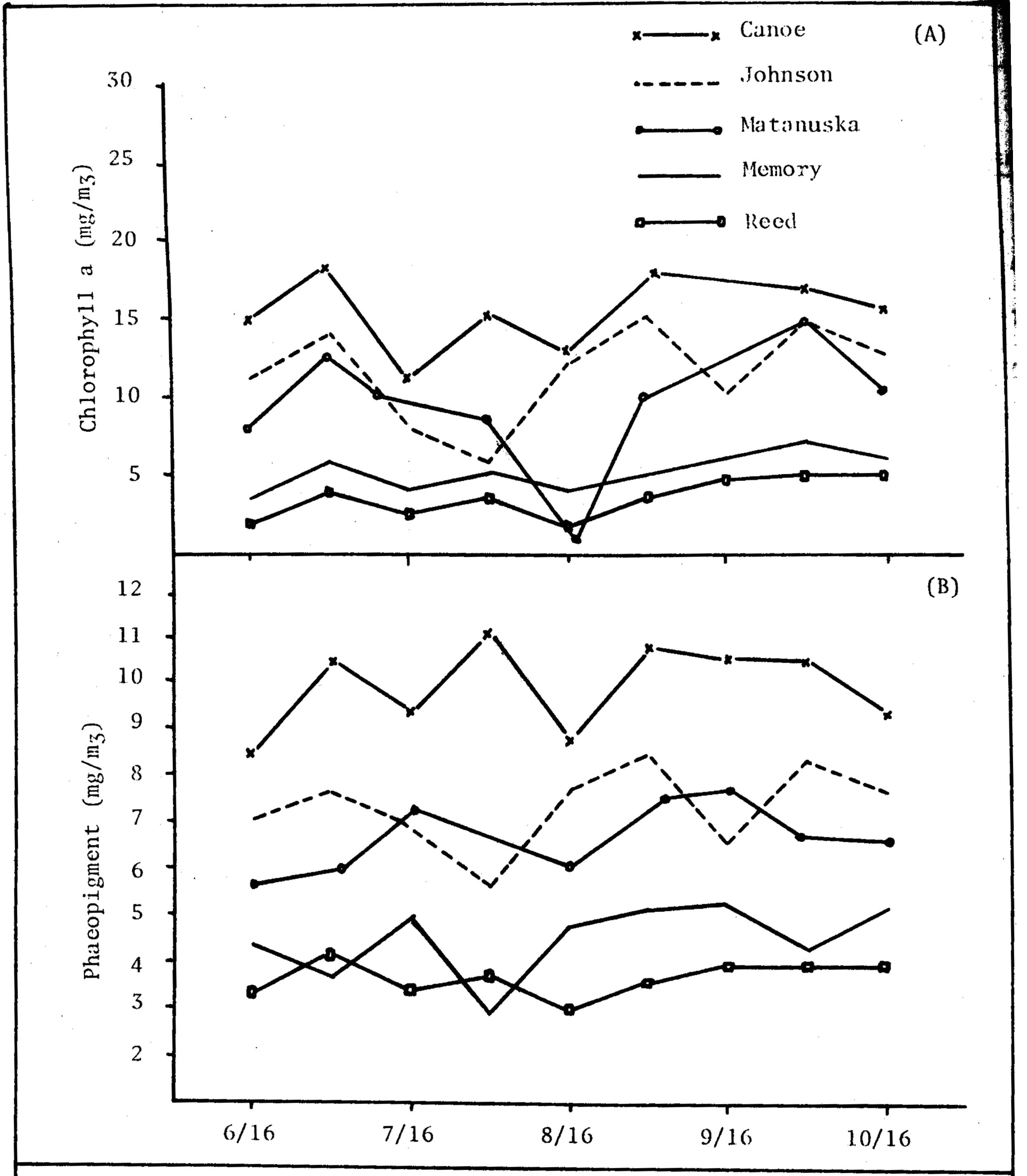


Figure 8. (A) Frequency of Chlorophyll a Volumes in Study Lakes, 1975.
(B) Frequency of Phaeopigment Volumes in Study Lakes, 1975.



1976

Figure 9. (A) Frequency of Chlorophyll a Volumes in Study Lakes, 1976.
(B) Frequency of Phaeopigment Volumes in Study Lakes, 1976

had stable hypolmnion temperatures near 40°F. Lake waters are characterized by a predominance of Ca^{++} among cations and HCO_3 among anions. Summer pH of surface waters ranged from 6.7 to 9.1. Lakes were subsequently ranked in a high to low order with respect to conductance, total hardness, and total alkalinity by Watsjold (1976, Table 5).

Watsjold (1975) states that on the basis of conductance values alone, waters with values less than 100 micromhos/cm generally yield much poorer gill net catches than those having greater electrolytic concentrations. Watsjold (1976) also states that although a simple ranking in high-to-low order with respect to conductance explains some differences in production between different bodies of water, there are some lakes lower in the ranking that produce higher yields of fish than their ranked position would suggest. Therefore, factors in addition to ionic concentrations must be influencing the productivity in these lakes.

Ryder, et al. (1974) derived the morphoedaphic index (MEI) from a measure of total dissolved solids and morphometry (mean depth) of a lake to estimate production from biotic communities. Specific conductance values were used by Watsjold (1976) to compute MEI values during the spring overturn period. Lakes were arranged from highest MEI, most productive, to lakes of lower MEI or lakes of lesser fertility (Table 6).

Results of the limnological phase of study have definite fishery management application. The investigated indicators of biological productivity; i.e., plankton abundance, periphyton, chlorophyll a, water chemistry and the morphoedaphic index, strongly indicate a relative ranking of lake productivity. The various indices are compared to MEI because the MEI is readily determined from identifiable dissolved nutrient concentrations and morphometry of study lakes in the Matanuska-Susitna area.

Plankton index values of 1973 differed from 1974 values. Johnson and Memory lakes had been chemically rehabilitated in the fall of 1973, possibly accounting for the observed differences in PI values. Figure 10 depicts PI on MEI correlations for study lakes, 1973-1976. Plankton index values determined in 1975 were higher than PI values of 1974, although not equal to values prior to rotenone treatment. Values determined in 1976 are higher and indicate that plankton production is similar to pre-treatment data. Kalb (1975) noted that rotenone treatment retarded zooplankton productions; however, comparison of the PI-MEI linear regressions by analysis of covariance (Kalb, 1975) shows no significant difference between slopes determined for 1973 and 1974; however, slopes of 1975 and 1976 PI-MEI linear regressions indicate a difference between slopes of 1973 and 1974. This difference may in part be caused by the number of lakes for which PI values were determined, i.e., 3 in 1975 and 1976 and 10 in both 1973 and 1974. Despite the above differences there is a strong relation between PI and MEI as indicated by correlation coefficients of PI regressed MEI; i.e., 1973--0.78, 1974--0.88, 1975--0.81 and 1976--0.99.

Table 5. Chemical Analysis of Selected Lakes of the Matanuska-Susitna Valleys (Engel, 1974; Watsjold, 1975).

Lake	Specific Conductance (micromhos/cm at 25°)	Total Hardness	Total Alkalinity
		---------mg/liter as $CaCO_3$---------	
Kepler	344	160	139
Echo	307	140	218
Matanuska	286	130	131
Canoe	277	130	112
Harriet	265	120	126
Long	246	120	113
Falk	234	110	105
Junction	234	110	111
Victor	228	110	99
Irene	221	100	99
Klaire	219	110	108
Finger	206	98	107
High Ridge	193	85	85
Bairds	184	85	89
Knik	174	81	86
Johnson	148	64	71
Florence	137	69	69
Lucille	134	60	66
Meirs	122	41	50
Seymour	102	47	48
17-mile	65	23	29
Reed	54	22	25
Memory	41	18	21
Benka	41	16	18
Wishbone	41	15	20
Christiansen	40	19	20
Rocky	40	17	20
Byers	36	17	15
Tigger	34	12	16
South Rolly	31	13	19
Carpenter	29	11	12
Milo # 1	19	5	7
Big No Luck	17	8	6
Chicken	14	4	6
Loon	13	5	5
Prator	11	3	4
12-mile	10	2	3
Marion	9	3	4

Table 6. Morphoedaphic Index Values for Selected Lakes in the Matanuska-Susitna Valleys (Watsjold, 1976).

Lake	MEI	Lake	MEI
Lucille	23.5	Memory	5.3
Harriet	21.3	Reed	4.9
Canoe	18.1	Meirs	3.4
Falk	16.7	Rocky	3.1
Echo	15.9	Christiansen	1.8
Seymour	14.6	Benka	1.3
Finger	13.3	Loon	1.3
Junction	13.2	South Rolly	1.2
Kepler	11.6	Big No Luck	1.1
Irene	10.4	Twelvemile	1.0
Long	9.4	Prator	0.9
Victor	9.3	Milo # 1	0.7
Knik	9.1	Chicken	0.5
Matanuska	8.2	Byers	0.5
Florence	7.6	Marion	0.4
Johnson	7.4		

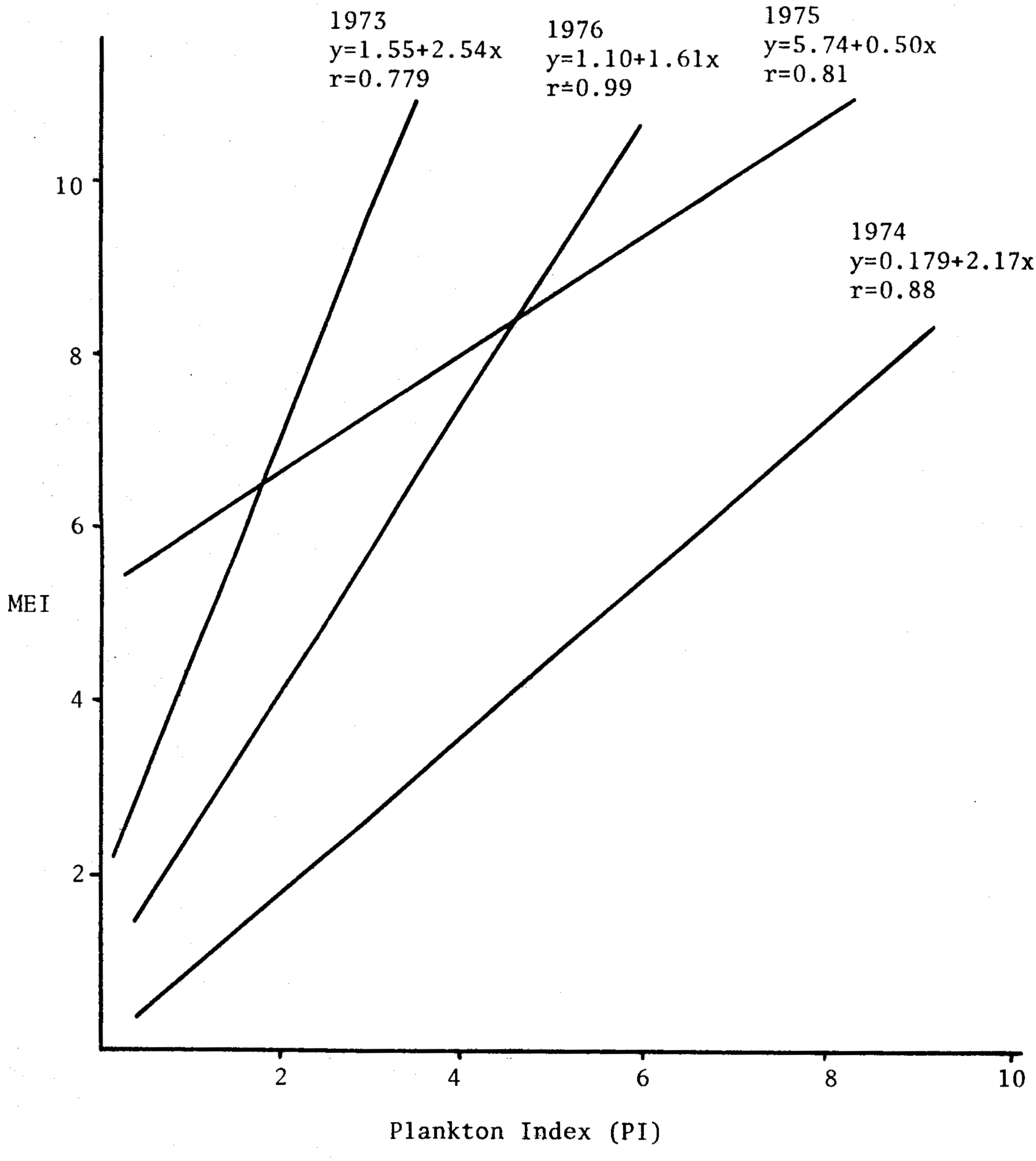


Figure 10. Linear Regressions of Morphoedaphic Index (MEI) on Plankton Index (PI), 1973-1976.

Regression analysis of periphyton biomass (g/m^2) determined for study lakes on a monthly sampling basis, 1975, yielded a high correlation of data, r=0.97, to the morphoedaphic index, Figure 11. A similar analysis of study lakes in 1976 also yielded high data correlation, r=0.96. Based on the two years of data, the relation to MEI is significant and indicates strong agreement of periphyton biomass to MEI as an indicator or productivity.

Concentrations of chlorophyll pigment as determined from study lakes were not regressed on the MEI; however, a quantitative relation of study lakes results in a relative ranking of pigment production (Figure 9).

Detailed chemical characteristics of 38 Matanuska-Susitna Valley lakes (Engel, 1974 and Watsjold, 1975), Table 5, results in a high-to-low order of ranking with respect to conductance, total hardness and total alkalinity.

The morphoedaphic index values as determined by Watsjold (1976) resulted in an arrangement of lakes having high MEI, most productive, to lakes of lower MEI or lakes of lesser productivity, Table 6.

Combining the various indices of productivity in tabular form a relative ranking is indicted, Table 7. Watsjold (1976) employed a numerical comparison of biological, chemical, and physical properties with the morphoedaphic indices for selected Matanuska-Susitna Valley lakes. He found that a regression analysis between the point totals of plankton index, mean depth, water chemistry, oxygen deficiency and MEI of each lake revealed a strong linear relation, r=0.92. It then becomes quite evident that whatever index the biologist chooses to investigate, a ranking of relative productivity may be derived; however, due to ease of determination of MEI and its close correlation to other indices, it is recommended that MEI be used for most purposes in establishing a ranking of lake productivity.

Other results derived from the limnological studies and pertinent to the management of sport fish waters have been an assessment of rehabilitation and identification of both macro and micro invertebrates. Comparing zooplankton trends in lakes chemically treated to eliminate undesirable fish populations with trends in a nontreated lake having a stable zooplankton community indicates that treated lakes require between one and two years to reestablish zooplankton production and three years to attain a production level of previous dominance and abundance. It is apparent that none of the abundant species of zooplankton were eliminated from lakes after chemical treatment. However, though a lake may detoxify in one year, further zooplankton community alteration is possibly due to the feeding behavior of trout introduced soon after detoxification. Though food habit studies of trout in varied lentic environments of Matanuska-Susitna lakes have not formally begun, the initial identification of macro and micro invertebrates will be useful in projected food habit studies. As the limnological studies continue, the accumulated information from productivity studies, assessment of rehabilitation, and identification of invertebrates provides useful aids in adjusting fish stocking densities in sport fish managed lakes.

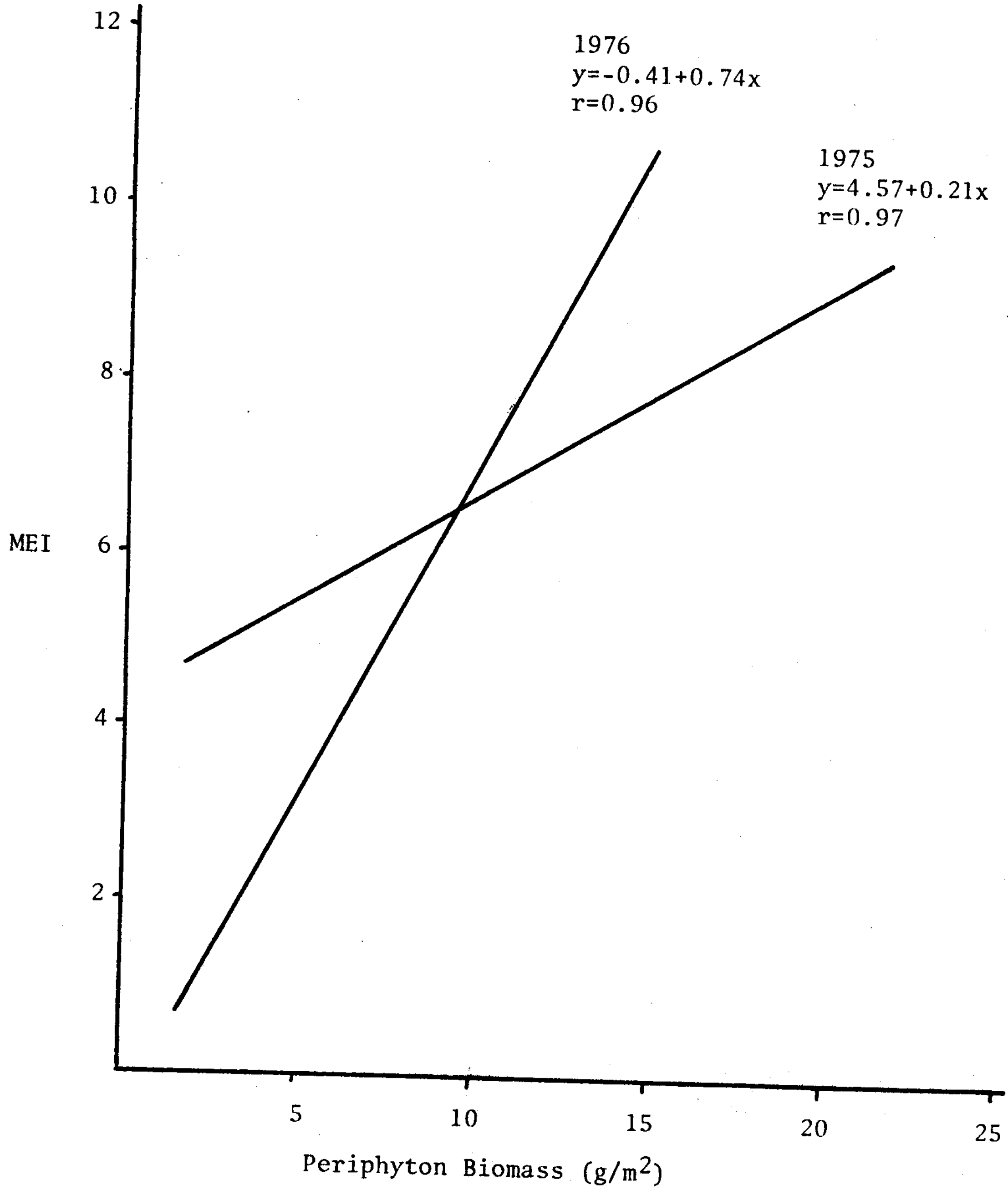


Figure 11. Linear Regression of Morphoedaphic Index (MEI) on Periphyton Biomass (g/m^2), 1975-1976.

Table 7. Ranking of Study Lakes Based on Investigated Indices, 1976.

	INDICE INVESTIGATED				
	Plankton	Periphyton	Chlorophyll	Water Chemistry	MEI
		Canoe	Canoe	Matanuska	Canoe
igher	Matanuska		Matanuska	Canoe	Matanuska
	Johnson	Johnson	Johnson	Johnson	Johnson
ower	Memory	Memory	Memory	Reed	Memory
			Reed	Memory	Reed

Lake Stocking Evaluation Study:

Since game fish stocking does not always produce desired results in the lentic environments of Alaska, it is important that the effects of various physical and biological parameters on fish be identified and analyzed. Stocking densities should be adjusted to minimize negative effects on fish. Accordingly, detailed limnological and physical data have been collected for lakes in the Matanuska-Susitna valleys. Statistical calculations comparing the indices derived from these data indicate that the various indices can be used as relative measures of biological lake productivity. Many of these lakes are located within a convenient one hour drive of Anchorage. As the state's population and tourism industry grows, game fish stocking in landlocked lakes is playing an increasingly important role in maintenance of fishing opportunity.

Fish studies included: (1) evaluation of trout survival in stickleback and non-stickleback environments; (2) survival, growth and total production of stocked game fish at different stocking densities in lakes of varying limnological characteristics; (3) an evaluation of domestic and wild trout strains in varied lentic environments; (4) a comparison of fry and fingerling plants; and (5) an evaluation of the British Columbia stocking curve.

Rainbow trout studies have involved several different lakes at one time or another; however, definitive trout investigations in Johnson Lake have been ongoing since 1969, due largely to a provision for closing the lake to fishing.

Johnson Lake encompasses a surface area of 40 acres having a maximum depth of 41 feet and a mean depth of 20 feet. It lies in the heart of prime Matanuska Valley farm land and probably derives much of its fertility from the surrounding soil type and climatic conditions (wind blown deposits). In comparison to other Matanuska-Susitna Valley lakes Johnson Lake is considered a moderately productive lake (Table 6).

Prior to September, 1973 Johnson Lake was inhabited largely by stickleback and stocked annually with rainbow trout. This same year constituted the year of assessing survival rates of rainbow trout from time of stocking to the following spring when age I trout reach catchable size.

The initial project design was to determine survival and growth of rainbow trout fingerlings under varying stocking conditions when in competition with indigenous threespine stickleback. A total of 2,496 fingerling trout, weighing 187/kg (85 per pound), were stocked in Johnson Lake on September 4, 1969 at a density of 153 fish per surface hectare (62 fish per surface acre). No older game fish were present. Survival of this plant was evaluated by Redick (1971) in the spring of 1970. Redick reported a survival of 24.3%. In 1971, additional data were collected on the survival of the 1969 planting after which Redick (1972) concluded that the final survival estimate of the 1969 planting approximated 25%.

The second planting was designed to duplicate stocking procedures in terms of planting density and fingerling size for use in managed lakes of the Matanuska and Susitna Valleys. In August, 1974, 7,446 rainbow trout, weighing 549/kg (349 per pound), were stocked in Johnson Lake at a density of 452 fish per hectare (183 fish per surface acre). A few Age I trout from the 1969 plant and an indigenous population of threespine stickleback were already present in the lake. A total of 322 hours of gillnetting was conducted the following spring during May and June. Not a single individual from the 1970 plant was recovered, which indicated few, if any, fish survived to a catchable size.

In June, 1971, 12,018 rainbow trout fingerling were planted in Johnson Lake. This plant consisted of three different sizes of rainbow trout which were stocked at a total combined density of 741 fish per surface hectare (300 fish per surface acre). Various numbers and sizes of trout stocked are as follows: 4,419 fish at 194/kg (88/pound) LV finclip, 3,628 fish at 212/kg (96/pound) RV finclip, and 3,971 fish at 734/kg (333/pound) no clip. It was expected that rainbow trout weighing 194 and 212 per kilogram would have greater survival 734/kg fish; however, a subsequent population estimate using the Peterson estimator at the 95% confidency interval indicated the reverse. Marked fish initially weighing 194, 212, and 734/kg had respective survival estimates of 3%, 3.5%, and 4.1%. Again, no measurable survival was indicated for fall, 1970, planted trout.

Examination of all population data, 1970-1972, indicated greater survival for larger fish when they were stocked at lower densities, Table 8. Based on this, it was decided to make a final rainbow trout plant using the largest size fingerling available and stocking at a medium density.

Table 8. Summary of Rainbow Trout Stocking Histories, Population Estimates and Biomass in Study Lakes.

Lake	Stocking History						Estimates After One Year		Biomass* Surface Acre	
	Stocked	Number	Per kg	Per lb	Per Ha	Per Acre	Population Size	Survival	Ha/	Acre/
Johnson	1969	2,496	39	85	153	62	606	24.3%	1.5	0.6
	1970	7,446	158	349	452	183	NO FISH RECOVERED			
	1971**	4,419	40	88			126	2.9%		
		3,628	44	96	741	300	128	3.5%	6.2	2.5
		3,971	154	333			161	4.1%		
	1972	7,875	15	34	494	200	1,770	22.0%	18.5	7.5
	1975***	12,000	91	200	741	300	1,639	13.6%	56.8	23.5
Short Pine	1973	15,600	54	119	741	300	2,110	13.5%	17.0	6.9
Marion	1974	20,300	433	955	185	75	1,649	8.0%	7.2	2.9
Christiansen	1974	63,500	433	955	371	150	1,778	2.8%	2.7	1.1

* Based on population estimate of survival for that year's stocking.
** Total number of fish stocked was 12,018 at a combined density equal to 300 fish per surface acre.
*** Stocking duplicates 1971.

This plant was made in August, 1972, comprising 7,875 fingerling trout at 75/kg (34/pound) at a density of 494/hectare (200/acre). The subsequent population estimate in spring, 1973, using Bailey's modification of the Peterson estimator at the 95% confidence interval resulted in an estimate of 1,700 trout or a 22% survival of the August, 1972 plant.

The 1972 rainbow plant marked the completion of the first phase of study in stickleback waters. A complete kill of sticklebacks was obtained after fall rotenoning in 1973. Johnson Lake had detoxified during the following winter but lay fallow the entire summer of 1974. The first post-chemical treatment stocking of rainbow trout occurred in July of 1975 with a plant of 12,000/207 lb. or 300 fish per surface acre. This stocking was intended to duplicate stocking densities in other lakes of the Matanuska-Susitna Valleys, and to achieve comparable or higher survival than prior stockings. At the 95% confidence interval the population size in spring, 1976, of the July, 1975 rainbow trout plant was an estimated 1,639 fish or 8% of the original plant.

Data thus far collected from rainbow trout survival studies in Johnson Lake, Table 8, indicate that numerical survival of fish is increased when competitor species, such as threespine stickleback, are eradicated. In a stickleback environment, fish survival is enhanced when larger fish were stocked at lower densities. It is recommended that rainbow trout planted in moderately productive waters containing stickleback be stocked at 85-185 fish per kilogram and at a density of 250-370 fish per hectare (100-150 fish per acre). A more comprehensive understanding of raising trout to a catchable size may be further realized through calculations of biomass and cost of raising fish up to the time of stocking. Biomass of rainbow trout in Johnson Lake, 1970-1975, was determined by multiplying average individual weight by the estimated size of the fish population. The results are presented in Table 8.

Production cost for salmon and trout at Fire Lake Hatchery (Joe Wallis, unpublished data, 1972-1973), Table 9, and the cost of developing catchable rainbow trout was computed. Production cost does not include egg takes because of the inconsistent dollar value of such operations, but represents the cost involved in wages, feeding, etc., from the moment fish eggs are placed in the hatchery through stocking. For example, using data from Johnson Lake 1972-73, the estimated value per fish at an average size of 75/kg (34/pound) was $0.12. The transportation cost for the total planting was approximately $30. Thus the total expense of planting 7,875 fingerling was $975. The harvest rate for age I fish would vary depending on fishing intensity, so the estimated value to the creel per fish was calculated for 100%, 75% and 50% harvest levels. Costs are presented in detail for lakes for which survival and biomass data are available, (Tables 10 and 11). From this it is readily apparent that when similar age I population levels are reached in, for example, a 1972 stickleback environment and 1975 a non-stickleback environment, the cost to the creel or cost of raising a catchable fish in a stickleback environment is more than two times as great. The cost per pound is 9

Table 9. Production Cost for Salmon and Trout at Fire Lake Hatchery, 1972-1973.

Average Size Fish/lb.	Fish/kg.	Estimated Cost in Dollars Per 100,000 Fish	Cost in Dollars of Fish Per lb.	Per kg.
1,000	454	2,000	20.00	9.08
300	136	2,000	6.50	2.95
250	113	2,200	5.50	2.50
150	68	3,200	4.80	2.18
100	45	4,600	4.60	2.09
50	23	9,000	4.50	2.04
Smolt	9-20			

times greater in a stickleback than in a non stickleback environment, Table 11. Rehabilitation of Johnson Lake with rotenone to eliminate stickleback totaled $915 or spread over a ten year period, $91.50 per year. The cost of rehabilitation is small compared to the value of increasing the number and poundage of sport fish. The $91.50 cost is further diminished when increased biomass carries over into future years, particularly with subsequent plants of trout. Notation should be given to the fact that biomass and survival computations were made on the 1975 stocking during mid-May 1976 and that biomass calculations at the end of June yielded 45.67 lbs./acre, almost a twofold increase over the 23.6 lbs./acre of mid-May.

Lakes including Short Pine, Marion and Christiansen also have biomass and population estimates and are characterized by lower productivity levels, while Johnson Lake is considered a moderately productive lake. Population estimates and biomass determinations for rainbow trout in Short Pine, Marion, and Christiansen lakes are also presented in Tables 10 and 11. Based on the estimated cost to the creel and on the survival of trout in low production lakes, it is readily apparent that survival of fry and small fingerling will be consistently lower than 15% of the original plant and that cost of producing a catchable fish will be quite high, i.e., $0.40 to $2.00 at a 50% harvest level. Kubik (1977) found from creel census data on four intensively fished lakes near Anchorage a harvest rate ranging from 46.9% to 78%, or a combined average harvest of 65%. Creel census work has not been conducted for Matanuska-Susitna Valley study lakes, however it is felt that a 50% harvest rate would be representative of managed lakes. It should be noted that this harvest rate may fluctuate depending on the quality of fishing.

Table 10. Estimated Stocking Cost of Rainbow Trout in Study Lakes.

Lake	Year	Population Size	Survival	Biomass (lbs/acre)	Stocking Cost* Total	Stocking Cost* Per Fish
Johnson	1969	606	24.3%	0.6	$ 170	$0.07
	1970		NO FISH RECOVERED		$ 175	$0.02
	1971	415	3.5%	2.5	$ 258	$0.02
	1972	1,770	22.0%	4.5	$ 975	$0.12
	1975**	1,639	13.6%	23.5	$ 348	$0.03
Short Pine	1973	2,110	13.5%	6.7	$ 372	$0.02
Marion	1974	1,649	8.0%	2.9	$ 678	$0.02
Christiansen	1974	1,778	2.8%	1.1	$1,207	$0.02

* Based on initial stocking history, i.e., number of fish stocked, number per pound, total pounds stocked, number total pounds stocked per surface acre and transportation costs.

Table 11. Estimated Cost to the Creel of Rainbow Trout in Study Lakes.

Lake	Sticklebacks Present	Year	Cost to the Creel by Percent Harvest					
			100%		75%		50%	
			Per Fish	Per Lb. Fish	Per Fish	Per Lb. Fish	Per Fish	Per Lb. Fish
Johnson	X	1969	$0.28	$7.00	$0.42	$10.50	$0.56	$14.00
	X	1970	NO FISH RECOVERED					
	X	1971	$0.62	$2.58	$0.93	$ 3.87	$1.24	$ 5.16
	X	1972	$0.50	$3.23	$0.66	$ 4.81	$0.99	$ 6.39
		1975*	$0.21	$0.37	$0.31	$ 0.52	$0.42	$ 0.74
Short Pine	X	1973	$0.18	$1.04	$0.27	$ 1.56	$0.36	$ 2.08
Marion	X	1974	$0.41	$2.05	$0.62	$ 3.07	$0.82	$ 4.10
Christiansen	X	1974	$0.68	$3.09	$1.02	$ 4.64	$1.35	$ 6.19

* 1975 was the first year of stocking in Johnson Lake after rehabilitation.

The low survival of domestic fish (Ennis and Winthrop rainbow trout strains) in study lakes are not uncommon to Alaskan lakes. Thus far, available data from Matanuska-Susitna study lakes indicate that 25% is about the maximum for domestic fish in low to moderately productive lakes. Similar survivals of stocked rainbow trout for interior Alaska lakes were also noted by Peckham (1974 and 1975).

Prior to 1975, rainbow trout eggs from Ennis, Montana and Winthrop, Washington, supported the state's trout cultural program. Both strains have extensive hatchery histories which resulted in great vulnerability to Alaska's environmental conditions. Because of the low survivals, high cost to the creel, and the risk of possible importation of disease organisms, Alaskan brood stocks are being developed and evaluated. Wild fish egg sources for these stocks are from Swanson River on the Kenai Peninsula and Talarik Creek in the Bristol Bay area. Bristol Bay trout were chosen primarily for their large size and Kenai fish because of possible greater tolerance to stickleback competition.

Evaluation of stocked wild fish is limited because this phase of study has been in existence for only two years; however, relative catch per unit effort CPUE (fish caught per net hour) comparisons between stocked lakes having wild fish may be made. For instance, Johnson Lake, (moderate productivity), and Marion and Christiansen lakes (low productivity), stocked with domestic strains of fish have respective CPUE values of 0.73, 0.24 and 0.63; whereas Reed and Big No Luck lakes, both of low productivity, stocked with wild strains of fish have respective CPUE of 5.24 and 4.50. Unfortunately, the means for determining percent survival of the original plant were not available; however, gillnetting of Reed Lake yielded 7% of the original plant and 4% of the Big No Luck plant. With the high percent caught of the original plants in Reed and Big No Luck lakes, the computed CPUE for both lakes indicates high survival of the stocked wild fish. This becomes most beneficial in terms of cost to the creel. With such a high CPUE of wild fish (indicating high survival) and low CPUE of domestic fish, it becomes quite evident that future wild fish studies are needed particularly when preliminary data indicate that the wild fish may be produced at a significantly lower cost to the creel.

In the development of an Alaskan brood stock from wild fish, strain analysis would also be beneficial in determining cost to the creel. One strain of fish may be consistently more tolerant to local lake conditions, thereby reducing cost to the creel. To date, four lakes of varying productivity, ranging from Reed and Big No Luck lakes of low MEI, Long Lake with a moderately high MEI, to Canoe Lake, one of the most productive lakes in the Matanuska-Susitna area, have been stocked with rainbow trout having Alaskan origins from Swanson River and Talarik Creek (Table 12). In 1974, Reed Lake was stocked with 1,500 right ventral fin clipped Swanson strain rainbows, 2,578 left ventral fin clipped Talarik strain rainbows, and 3,000 unmarked Talarik strain rainbows. Chi-square analysis (Chlupach, 1976) indicated significant difference ($p = 0.01$, d.f.=2) in gill net catches of Swanson and Talarik fish. Higher than expected catches of Swanson fish occurred. Number and size differentiation of rainbows stocked does not seem significant

Table 12. Lake Stocking Schedule for Talarik-Swanson Rainbow Trout in Study Lakes.

Lake	Date Stocked	Strain*	Size		Stocking Density		Number of Fish
			Fish/kg	Fish/lb	Fish/ha	Fish/acre	
Canoe	10/01/75	T	102	226	309	125	2,625
		S	132	292	309	125	2,625
Big No Luck	10/01/75	T	102	225	84	34	2,300
		S	134	296	163	66	4,500
Long	6/20/75	T	5	11	101	41	3,056
		S	5	11	35	14	1,000
Reed	10/10/75	T	44	98	689	279	5,578
		S	60	132	185	75	1,500
Irene	10/05/76	T	53	117	247	100	2,100
		S	103	227	247	100	2,100
Marion	10/04/76	T	53	117	94	38	4,250
		S	103	227	94	38	4,250

* Talarik from Bristol Bay trout, Swanson from Kenai Peninsula.

Table 13. Catch by Gill Net of Marked Swanson River and Unmarked Talarik Creek Rainbow Trout Strains in Big No Luck Lake, 1976.

Categories		Groups	
		Swanson	Talarik
Gill Netted	Observed	249	55
	Expected*	201	100
Estimated Non-Gill Netted	Observed	4,299	2,200
	Expected	4,488	2,244

* Expected frequency equals the proportion at time of planting, times total gill netted rainbow.

as Swanson fish were stocked at a smaller size and in fewer numbers; however, the greater catch could be explained by a better survival. Population estimates were not made in Reed Lake but an indication of representative survival may be gained from gill net catches. Gill-netting one year after stocking yielded a total catch of 524 fish, or 5.24 fish per gill net hour. Population composition by percent for each strain at time of stocking was 21% marked Swanson, 42% marked Talarik, and 36% unmarked Talarik. Percent composition by strain of the gillnet sample was 23% marked Swanson, 28% marked Talarik, and 48% unmarked Talarik. In 1976 two additional lakes, Irene of moderately high productivity, and Marion, of very low productivity, were stocked with equal numbers of Talarik and Swanson strains of trout. Evaluation of both lakes is scheduled for May, 1977. To date lakes stocked with Talarik and Swanson fish in 1974 and 1975 have indicated definite differences in survivals between the two strains.

Long Lake was stocked in the spring of 1975 with 1,000 marked Swanson River rainbow and 3,056 unmarked Talarik rainbow. Subsequent gill-netting yielded catches of 81 Swanson fish and 46 Talarik fish. Chi-square analysis (Chlupach, 1976) of data indicate significant difference (p 0.0.1, d.f.=1) in catches where more marked Swanson fish than expected were captured as opposed to the catch of fewer unmarked Talarik. Composition for each strain at time of stocking was 20% Swanson fish and 80% Talarik fish whereas gillnetting composition was 63% Swanson and 37% Talarik.

Big No Luck and Canoe lakes were stocked in October, 1975 with marked Swanson River and Talarik rainbow. Subsequent gillnetting of Big No Luck Lake yielded catches of 249 Swanson fish and 55 Talarik fish. Chi-square analysis (p 0.01, d.f.=1) of data (Table 13) indicates significant difference in catch where more marked Swanson fish than expected were caught. At the time of stocking, percent composition for Swanson and Talarik was 66% and 33%, respectively, and gillnetting one year later resulted in 81% Swanson fish and 18% Talarik fish.

Because of low dissolved oxygen levels in Canoe Lake of 0.0 ppm to 2.5 ppm recorded in late February and early March (1976), it was expected that all of the fish had been killed. Subsequent gill netting in September yielded a catch of 70 Swanson fish and two Talarik fish, or a catch composition of 97% Swanson and 3% Talarik fish. The two strains had been stocked at equal densities in October, 1975.

Cost to the creel for Alaskan brood stock from wild fish is not determinable at this time but studies thus far conducted in analysis of Alaskan strain rainbow trout in the Matanuska-Susitna Valley lakes indicate that when Swanson and Talarik fish are stocked in lakes ranging from high productivity to lakes of low productivity the Swanson fish seem to have greater tolerance to various lentic environments.

Another phase of study has been to compare Winthrop and Ennis stocks through evaluation of the suitability of applying the British Columbia stocking curve (Smith, et al., 1959) to Alaskan conditions. Initial stocking schedules were designed to approximate production capabilities of the Fire Lake Hatchery, and also to be flexible enough to adjust to growth variations among different strains of fish. Rainbow trout hatched from Winthrop, Washington, and Ennis, Montana, egg sources were selected for comparison because these strains were predominately used by the hatchery. As Ennis rainbow trout are mid-winter spawners, eggs are available to the hatchery at an early date, allowing a longer growth period prior to stocking than the Winthrop strain, which are spring spawners. When stocking lakes with Winthrop fry and Ennis fingerling, it was necessary to equate numbers of fry to numbers of fingerling from the British Columbia stocking curve so that fry planted produced age I catchable trout equal in number to trout produced by a fingerling plant. The British Columbia stocking curve has been evaluated for Winthrop-Ennis plants in four lakes: Long, Marion, Christiansen, and Irene. In Long Lake, Kalb (1974) found the Winthrop strain present in slightly greater numbers than Ennis strain fish, suggesting that the conversion schedule overestimated numbers of fry needed to equal numbers of the fingerling plant. Chlupach (1976) found from spring gill netting data, that the conversion schedule overestimated the number of fry needed to equal fingerling for Marion Lake and underestimated the number of fry needed to equal fingerling for Christiansen Lake. Further analysis of the stocking curve was not accomplished in either lake because it was impossible to differentiate the two strains on the basis of length frequency (Chlupach, 1976). The stocking curve could not be evaluated for Irene Lake fish as length frequencies (Figure 12) determined from spring gill netting results of the July, 1975 Winthrop-Ennis plant showed a lack of differentiation between Winthrop and Ennis strains. The British Columbia stocking curve as applied to stocking practices for lakes in the Matanuska-Susitna area has not been a successful tool in adjusting stocking schedules for Winthrop fry and Ennis fingerling.

Another stocking practice currently being evaluated is whether a spring or fall plant of rainbow trout is more beneficial to the sport fishery. Current data is limited and, analysis remains speculative. Matanuska Lake was stocked with an equal number of spring and fall plant rainbow trout in 1975. Population estimates were not made, consequently data analysis is limited to the ratio of marked to unmarked fish corresponding to the respective spring or fall plant. Noted imbalances of catch for spring and fall planted trout were not evident in spring gill netting, 1976 of Matanuska Lake; however, fall gill netting catches in August and September indicated a decline in representative numbers of the spring plant. In August, 8 fish from the spring plant and 58 fish from the fall plant were caught. In September, spring and fall plant catches were 16 and 35, respectively. No known cause for this is evident. However in other Alaskan lake studies, Peckham (1974 and 1975) found that following July stockings, population estimates of 18% and 26% of the original plants of two interior lakes indicated high initial mortality within the first two or three months.

Preliminary hook and line release investigations have been begun on stocked Johnson Lake fish. The main priority was to determine rainbow trout population size by marking hook and line caught fish. Secondary data analysis was oriented toward the effects of hook and line release.

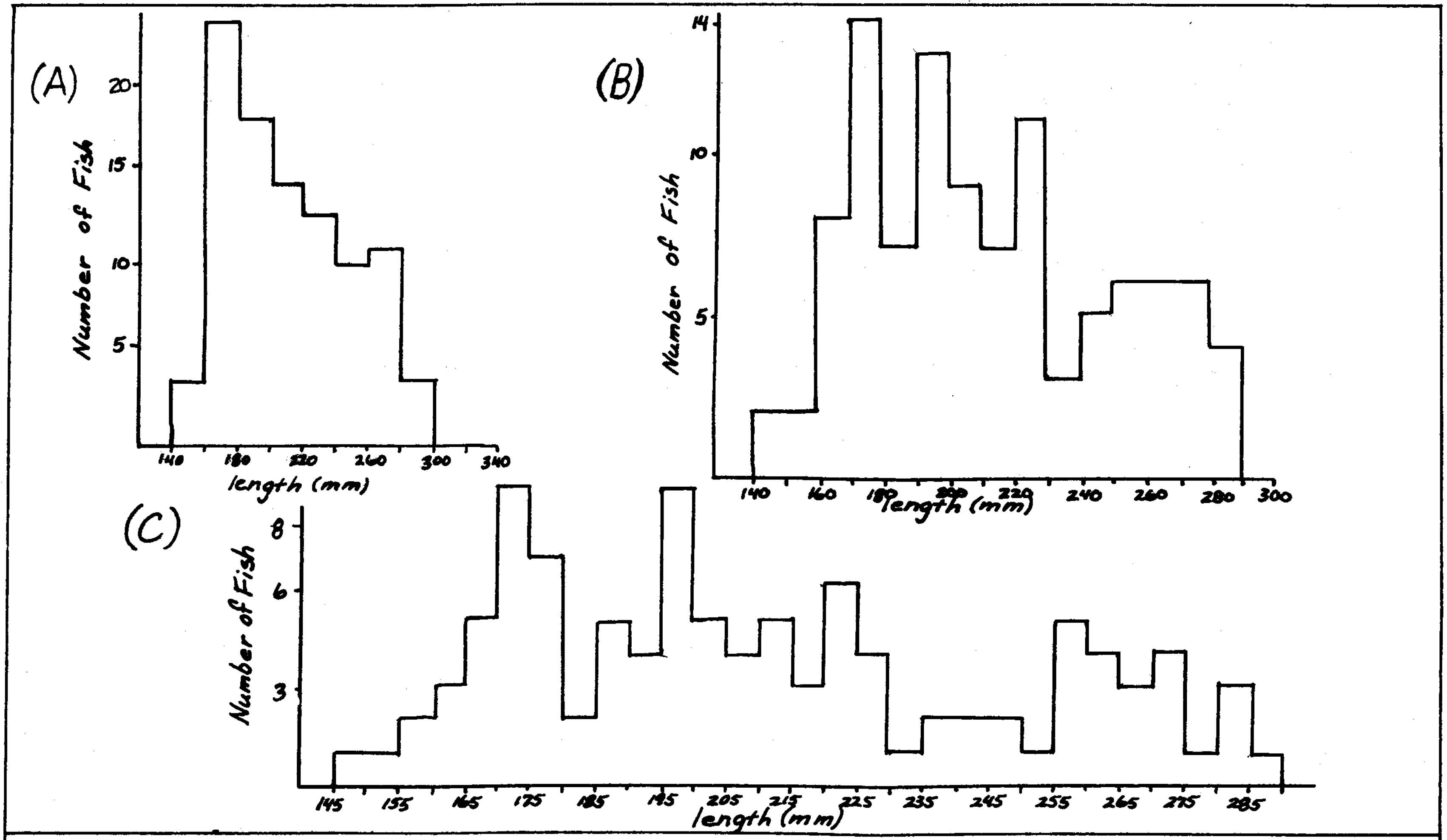


Figure 12. Inseparable length frequencies after spring gillnetting (1976) of the 1975 Winthrop fry and Ennis fingerling plants in Irene Lake.
(A) Length frequency in 20 mm intervals.
(B) Length frequency in 10 mm intervals.
(C) Length frequency in 5 mm intervals.

With the beginning of angling, June 3, 1976, fish were caught with little difficulty. As angling continued it became increasingly hard to catch fish, subsequently the lake was not fished for four days. When fishing was resumed, a substantial increase in CPUE was noted, Table 14.

From June 3 to June 22 a total of 286 trout were caught, of which 45 (16%) died. Of these mortalities, 40 occurred a short time after hooking. Only five mortalities occurred in the remaining 24 hour period. On June 14 a decision was made to remove one hook and to file barbs on the remaining two hooks. Up until this time mortalities represented 17% of captured fish. After alterations of terminal gear only a 4% mortality occurred. Anglers observed that with two hooks only occasionally was the lure taken deep; fewer external damages, namely to the eye, occurred and less time was involved in hook extraction which meant less handling out of the water. Gill net catches in July of marked and unmarked fish to make a population estimate yielded a 15% catch of marked fish. Fall gill netting catches in October resulted in 25% marked fish, indicating that there was no significant mortality of fish caught by hook and line in July after the initial mortalities and the 24-hour retention period prior to release. Variables considered, but not able to be incorporated in the results, were: What is the effect on fish of hooking and landing? How is a fish effected by being hooked twice? If mortality under such conditions ensues, how long before the existing population is significantly reduced? Also, fish mortality due to hook and line capture conducted by staff probably represents a minimum and does not answer the question of what mortality or survival factors potentially exist if the public were involved in hook and release fisheries studies.

Growth of Hatchery Fish:

Although project direction is not for the evaluation of trout strain survival during hatchery rearing, it may be beneficial for the fish culturist to know growth rates from year to year, particularly if program designs are directed toward selection of a viable strain for brood stock purposes.

Age 0+ Talarik and Swanson rainbow trout strains were randomly sampled from Elmendorf Cooling Ponds in June and September of 1975. Student's t-tests indicated a 95% probability that the differences in means of length and weight of the two strains sampled in June were not significant (Chlupach, 1976); however, student's t-tests of the same strains sampled in September indicated 95% probability of no significant difference in mean lengths but significant difference in weight with Swanson fish, an average of 23 grams heavier. A year later the same fish (I+ age) were sampled and it was found that lengths were statistically equal although Talarik fish were significantly heavier by an average of 36 gms. Sampling of the 1975 Talarik-Swanson broods t-tests for length and weight indicated that Talarik fish were significantly longer, by an average of 21 mm, and an average of 25 g heavier. Mean length and weight for 53 Talarik fish was 183 mm and 72 g.

Table 14. Johnson Lake Mark-Recapture Study, 1976.

Date	Number of People	Total Hours Fished	Total Hours Fished per Person	Total No. of Fish Caught	Immediate Fish Mortalities	Additional Fish Mortality in 24 Hours	Marked Fish Released	Catch/ Hour
6/3/76	4	14	3.5	38				2.7
6/4/76	2	5	2.5	42	5			8.4
6/6/76							75	
6/6/76	2	5	2.5	33	8			6.6
6/7/76	4	12	3.0	39	8	4	25	3.25
6/7/76	2	4	2.0	6				1.5
6/8/76	2	4	2.0	3			33	0.75
6/9/76							3	
6/14/76	2	10	5.0	53	16	1		6.9
6/15/76	2	4	2.0	18	3		36	4.5
6/21/76	2	6	3.0	6			15	1.0
6/22/76	6	14	2.3	48			6	3.4
6/23/76							48	
Totals		78		286	40	5	241	3.66

DISCUSSION

Assessment of estimates of biological productivity in Matanuska-Susitna Valley lakes includes data analysis of plankton, periphyton and chlorophyll production. When the estimators of biological productivity are evaluated with the morphoedaphic index it becomes evident that a ranking of relative productivity is derived. The index best fitting the biologist's needs in determining relative lake productivity should be evaluated over a period of years to learn whether that particular index is consistent with changing environmental trends. Due to ease in determining the morphoedaphic index and its close correlation to other indices, it is recommended that MEI for most purposes be used in establishing a ranking of lake productivity.

Elimination of the zooplankton community in study lakes did not occur after chemical treatment; however, comparison of zooplankton trends and plankton volumes of treated lakes with a lake having a stable zooplankton community indicates that treated lakes require between one and two years to reestablish significant zooplankton production and three years to attain a production level of previous dominance and abundance.

Data thus far collected from rainbow trout studies in Johnson Lake indicate that fish survival is increased when competitor species such as stickleback are eradicated. In a stickleback environment sport fish survival is enhanced when relatively large fish are stocked at relatively low densities. This is of importance to trout management when production costs are computed. For instance, in Johnson Lake when similar age I trout population levels in a stickleback habitat and a non-stickleback environment are compared, the cost to the creel of raising a catchable fish in a stickleback environment is two times greater (nine times greater when poundage production was considered) than the cost in a stickleback-free environment. Cost to the creel and creel census studies would also be useful when stocked lakes of varying productivities are evaluated on a cost/benefit basis. Along this same phase of study the low survival of plants of brood trout with long domestic histories has helped initiate studies related to the development of a brood stock from Alaskan trout. Definite cost to the creel for Alaskan brood stock is not determinable at this time because the means for determining population size and biomass have not been available; however, preliminary studies indicate that Alaskan trout, when stocked in lakes ranging from high productivity to lakes of low productivity, have a greater tolerance to various lentic environments than do the domestic fish. Other phases of study having possible cost/benefit implications have had moderate success; i.e., spring versus fall plants and fry-fingerling plants determined by the British Columbia stocking curve. Evaluation of the two management practices will continue until sufficient data for analysis is obtained.

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